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attempts to accommodate the contractor based on his composite attitude toward risk and utility, yet does not obstruct the Government's objective to minimize cost.

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A MATHEMATICAL MODEL FOR FIXED-PRICE-INCENTIVE-FIRM CONTRACTS

by

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ABSTRACT

This research focuses on a mathematical model for Fixed-Price-Incentive-Firm (FPIF) type contracts. The model revolves around the concept of a balanced trade-off among different options available to the user. At one extreme, the model develops a FPIF arrangement that gives the contractor a strong incentive to underrun costs, but strict penalties if he overruns. At the other extreme, the model develops a FPIF arrangement that gives the contractor minimal incentive to underrun, yet significant protection against an overrun. The mathematics of the model uses integral calculus to balance each of the options such that both the expected profit for the contractor and the expected cost to the Government do not change as the user selects different options. In this computation, the subjective probability density function for the cost is assumed to remain constant. This process attempts to accommodate the contractor based on his composite attitude toward risk and utility, yet does not obstruct the Government's objective to minimize cost.

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I. INTRODUCTION

Since the dawn of civilization, man, in his never ending quest to further his personal objectives, has learned to contract with his fellow citizens. Contracting encompassed all of man's endeavors. From the bartering in the marketplace to the agreements among kings, man quickly learned the principles of contracting and the art of negotiations. As society changed, contracting also changed. Through the centuries, as civilization evolved from serfdom monarchs into capitalistic democracies, contracting, likewise, grew in magnitude and complexity. One major development in contracting's evolution was the use of incentives. Basic contracting, the process through which two independent parties freely enter into an agreement, lacked the ability for one party to motivate the other. Incentive contracting, designed to fill this void, allowed one party to motivate behavior or "incentivize" the other party to perform in a specific way. With rewards and/or punishments, one party could "motivate" the other party to perform according to his own objectives. The better the performing party did, the higher she would be rewarded. Incentives encouraged creative approaches to contracting, opened communications

between both parties, and forced each party to consider the perspective of the opposite side.

A. MOTIVATION THEORY AND INCENTIVE CONTRACTING

Incentive contracting revolves around motivation theory. Although there are many renown motivational theories, two of the best recognized are Maslow's Hierarchy of Needs theory and Herzberg's Two-Factor theory. [Ref. 8:p. 14] Although neither of these theories addresses incentive contracting directly, both are important to understand what motivates man--the fundamental objective of an incentive contract.

Maslow's theory states that man is motivated by his hierarchy of needs. The most basic of man's needs are food, clothing, shelter, and safety--a reflection of man's environment. Next are more abstract needs such as self-esteem, acceptance, cognitive development, and challenge--a reflection of man's peers. Finally, at the top of the hierarchy are internal concepts such as aesthetic needs, beauty, symmetry, and eventually self-actualization--a reflection of man's self. Maslow believed that as man meets his basic needs, he strives to conquer his advanced needs until he reaches "self-actualization" or self-fulfillment. [Ref. 12:pp. 309-311]

Herzberg's Two-Factor theory divides motivation into two categories: hygiene and satisfier. Hygiene factors only

affect job dissatisfaction. Typical examples of hygiene factors are working conditions, interpersonal relations, quality of supervision, and salary. Consider the following example regarding working conditions. A worker may be unhappy because her office is too noisy. The next day, if the manager reduces the noise level, that worker will not necessarily be satisfied with her job. She will only cease being unhappy. In other words, hygiene factors do not bring job satisfaction. At best hygiene factors can only prevent job dissatisfaction. The second category, satisfiers, on the other hand, can bring job satisfaction. These typically include the more abstract: achievement, recognition, responsibility, advancement, and growth. Herzberg's theory contends that these two categories (hygiene and satisfiers) are mutually exclusive. That is although satisfiers can bring job satisfaction, they cannot prevent job dissatisfaction. Essentially, the two factors are separate dimensions. [Ref. 13:pp. 57-63]

Although neither Maslow or Herzberg's theories focus on incentive contracts, both concepts are important to understanding human nature. When developing an incentive contract with a company, one must know what will motivate that company. Is the company driven by higher profits? Perhaps the company is content with its financial position

and only seeks challenging work or scientific recognition. Maybe the company is risk averse and wants protection against expensive overruns. Only by understanding the contractor's objective can a buyer develop an incentive arrangement that will effectively motivate the contractor. Take for example, the Wright Brothers' airplane incentive contract.

In 1907 the Wright Brothers had an incentive contract that agreed to pay more for a faster aircraft and less for a slower aircraft. The base price for the contract was \$25,000. The expected speed of the aircraft was 40 miles per hour. The contract promised to pay the Wright Brothers according to Table 1.1:

TABLE 1.1 WRIGHT BROTHERS' CONTRACT

less than 36 mph	rejected
36 mph	60% of base price
37 mph	70% of base price
38 mph	80% of base price
39 mph	90% of base price
40 mph	100% of base price
41 mph	110% of base price
42 mph	120% of base price
43 mph	130% of base price
44 mph	140% of base price

In this contract the buyer sought a faster aircraft. The buyer wanted to motivate the Wright Brothers through higher profits. The Wright Brothers, like most people, preferred to earn higher profits (to build a faster aircraft) yet were still limited by physical constraints, technology, and capital investment. In this example the Wright Brothers

built an airplane that flew 42.5 mph, earning them an additional bonus of \$6,250. [Ref. 11:pp. 3-4] However, only the Wright Brothers will ever know if the incentive arrangement provided the primary motivation for their work. Perhaps, the Wright Brothers wanted fame more than the additional profits. If so, the incentive arrangement was not as effective as it could have been. If the Wright Brothers wanted fame, maybe if the buyer promised media exposure instead of higher profits, the plane might have flown 45 mph! The point of this example is to emphasize the paramount importance of understanding what motivates a contractor. Of course all contractors are limited by physical constraints, technology, capital, and human resources. Yet even within these boundaries, both parties benefit when a contractor is motivated through incentives to perform better than expected. Only with the knowledge of what will motivate a contractor can one develop an effective incentive contract.

Today, given the complexity of man's technological endeavors, incentive contracts have evolved into many partitions. These contract types include: Cost-Plus-Incentive-Fee, Cost-Plus-Award-Fee, Fixed-Price-Award-Fee, Fixed-Price-Incentive-Successive-Targets, and Fixed-Price-Incentive-Firm. For each of these contracts, there is a unique approach to "motivating" the contractor's behavior.

Some of these contract types attempt to motivate the contractor to control costs by paying them higher profits for lower costs. Others focus on performance. The better the contractor does on predetermined performance tests (such as speed in the Wright Brothers' contract) the more profit the contractor earns.

B. OBJECTIVE

This thesis focuses on the Fixed-Price-Incentive-Firm (FPIF) arrangement and attempts to develop a decision support system for this contract type. In the last few decades, the acquisition and technological environments have changed significantly. In the contracting community, acquisition planning has become more complex and entangled in legal ramifications. In the technological community, powerful desktop computers are as common as calculators were twenty years ago. Today, computers are an integrated tool for all businesses throughout the world. More than just data processors, computers serve as data bases, expert systems, artificial intelligence, and decision support systems. They help people make decisions. [Ref. 5:pp. 1-37] In the business community, computers assist decision-makers to analyze data. In the medical field, advanced computers work with doctors to diagnosis patients. In the entertainment field, computers generate detailed graphics for movies. In

the artificial intelligence arena, computers play chess at the grandmaster level and are beginning their siege on the world champion. [Ref. 6:p. 52] The fact is very clear: computers are an integrated part of man's decision-making process.

This thesis attempts to merge these changing communities by developing a mathematical model for FPIF contracts and implementing this model into a Pascal computer decision support system. (See Appendix A: Computer Program) To develop a model, the researcher first studied the human thought process, then modified these processes, making them applicable to a mathematical model. The model prompts the user for specific information regarding a FPIF arrangement, then based on the data, presents a potential FPIF pricing arrangement. The inputs required are the answers to specific questions regarding the contract. The output is the potential FPIF arrangement in tabular form including all basic characteristics of the pricing structure. Like all computer models, the output will only be as good as the input. Ultimately, the researcher hopes that this model will (1) exercise sound business judgment; (2) lay the foundation for contracting software; (3) become a valuable contracting tool for acquisition personnel; and (4) help contracting personnel understand the fundamentals of FPIF contracts.

C. RESEARCH QUESTIONS

The primary focus of this thesis is to develop a mathematical model for FPIF contracts and implement this model in a computer program. The specific research question is can a mathematical model be developed to assist contracting personnel analyze alternative pricing strategies for FPIF type contracts? The subsidiary questions are:

1. What inputs would the computer require to develop effective pricing arrangements for FPIF contracts?
2. How can the model assist contracting personnel by providing a means to ask "what if" questions that otherwise would have been too time consuming and calculation intensive?
3. In what way can the model effectively capture a "business strategy", making it an effective and reliable asset to decision-makers?

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The primary focus of this thesis is directed toward the mathematical model. The researcher's goal is to develop a mathematical model that systematically approaches a FPIF contract. Key calculations in the model are profit of the contractor, expected cost to the Government, and expected utility of the contractor. The secondary emphasis of the thesis is the computer program. Unfortunately, mathematical models often remain on the shelves of academic institutions.

The researcher hopes to implement a framework of the mathematical model into a simplified computer program. The computer program only performs the most basic functions of the model. The objective is not to design commercial quality software, but to create a basic tool that can transport the model from academia onto the desks of contracting personnel.

In developing the model, one fundamental assumption made throughout most of this thesis is a uniform cost distribution function within ± 3 standard deviations from the mean. A uniform cost distribution implies that all costs within ± 3 standard deviations have a equal probability of being the actual costs. In reality, cost functions tend to be normally distributed. The researcher makes this assumption in order to simplify the mathematics. Without this assumption, the integration would be complex. However, given that both distribution functions are symmetric about the mean, the overall mathematical effects of this assumption should not be significant. Furthermore, the emphasis of the model is on the mathematical processes not the specific mathematical functions.

E. METHODOLOGY

The researcher began by studying the human thought process for developing FPIF arrangements. After writing a case study regarding a FPIF contract, the researcher

presented the case to students in the Pricing and Negotiations Course at the Naval Postgraduate School. After analyzing the students' processes, the researcher developed a mathematical model that mimics the human thought processes, yet taps the resources available to a computer. The mathematics of the model focus on the expected profit of the contractor, the expected cost to the Government, and the expected utility of the contractor.

II. UNDERSTANDING FIXED-PRICE-INCENTIVE-FIRM CONTRACTS

Before one can fully appreciate a Fixed-Price-Incentive-Firm contract, one must understand the wider spectrum of contract types. There are two basic types of contracts: cost-reimbursable and fixed-price. [Ref. 1:p. 1-11] Cost-reimbursement is best suited for contracts with relatively high uncertainty as to the cost, performance, and schedule of completing the contract. [Ref. 1:p. 1-11] For cost-reimbursable contracts, the buyer agrees to pay the seller all allowable costs. In return, the seller guarantees best efforts to meet the terms and conditions of the contract. Essentially, since the buyer agrees to pay for all costs, he bears the burden of risk. [Ref. 1:p. 1-11]

The second basic contract type is fixed-price. Fixed-price arrangements are best suited for contracts with high certainty as to the expected cost, performance, and schedule of completing the contract. [Ref. 1:p. 1-11] For this type of contract the seller agrees to deliver the goods and/or services according to the terms and conditions of the contract regardless of the actual costs. [Ref. 1:p. 1-11] Since the seller, regardless of unforeseen delays or complications, must deliver the goods or services, the

seller bears the burden of risk. [Ref. 1:p. 1-11]

Stanley Sherman, professor at The George Washington University, explains the differences between the two contract types as:

The difference is expressed best in terms of the assumption of risks of the two parties. In the cost contract, the buyer assumes most of the financial risks of nonperformance or delayed performance. In the fixed-price contract, the supplier assumes most of the financial risk of nonperformance or delayed performance. [Ref. 14:p. 319]

However, since all contracts do not definitively fall into one of these two broad categories (the substantial gray area between certainty and uncertainty) there is a subset category between cost and fixed-price type contracts known as incentive contracts. Incentive contracts include: Cost-Plus-Incentive-Fee (CPIF), Cost-Plus-Award-Fee (CPAF), Fixed-Price-Award-Fee (FPAF), Fixed-Price-Incentive-Successive-Targets (FPIS), and, the subject of this thesis, Fixed-Price-Incentive-Firm (FPIF). Essentially, incentive contracts attempt to balance the risk between buyer and seller and motivate the contractor to perform. [Ref. 3:p. 5-32]

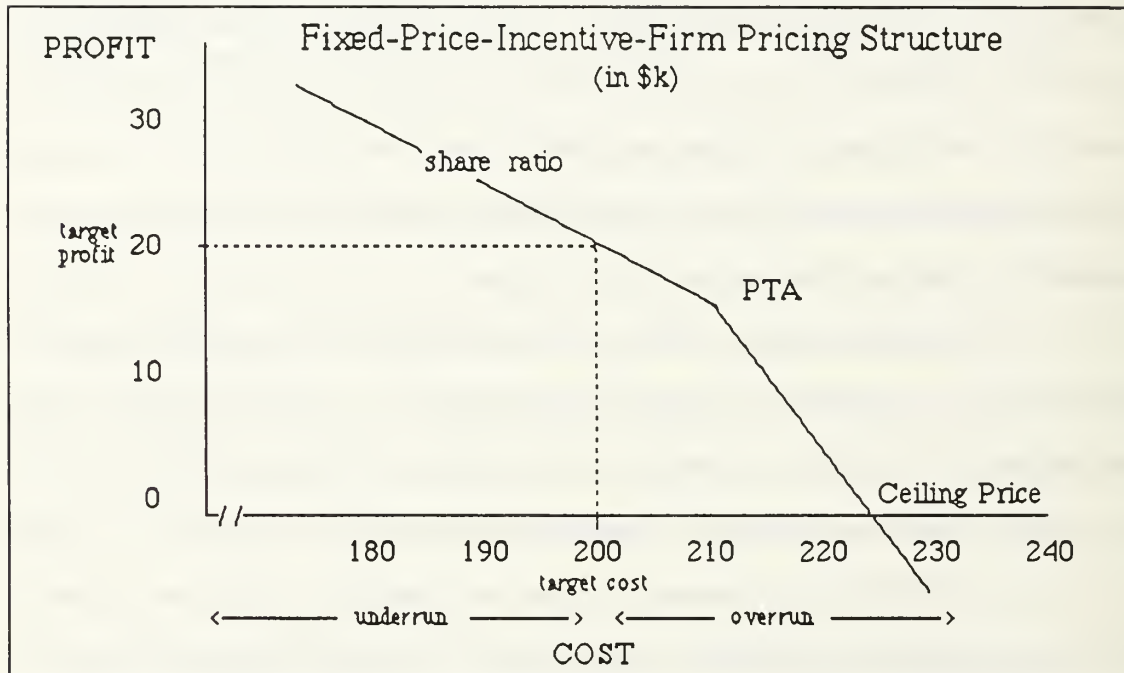
Fixed-Price-Incentive-Firm (FPIF) arrangements are best suited for contracts with substantial risk, but not enough to warrant a cost-type contract. Historically, FPIF contracts have been used for development contracts, low rate initial production contracts, and production contracts with

substantial uncertainty. [Ref. 7:pp. 1-2] As a general rule, FPIF contracts should be used when the difference between the highest and lowest cost proposal (in the competitive range) varies between 10% and 15%. [Ref. 3:p. 5-32] If the proposals vary less than 10%, the buyer might consider moving toward a Firm Fixed-Price contract. Likewise, if the proposals vary more than 15%, the buyer, given the higher uncertainty, might consider moving toward a cost-type contract. Although these parameters serve as an excellent guideline, these percentages should not be the sole reason for selecting a contract type.

In a FPIF contract, the buyer and seller share the cost risk within a predetermined range through a share ratio. At the upper limit of the range, the seller assumes all financial responsibility. Above the point of total assumption (PTA), for every dollar the seller overruns, the contractor loses a dollar of profit. If the overrun is so great such that all profit is exhausted, (ceiling price) the contractor not only loses all profit but incurs a loss. Figure 2.1 graphs a hypothetical contract (contractor's profit versus her actual costs). Most FPIF pricing arrangement can be characterized with six points: target cost, target profit, target price, share ratio, point of

total assumption and ceiling price. For the example shown in Figure 2.1, these six points are:

Target Cost:	\$200,000
Target Profit:	\$ 20,000
Target Price:	\$220,000
Share Ratio (Gov/Contractor):	50/50
Point of Total Assumption:	\$210,000
Ceiling Price:	\$225,000



Source: Developed by researcher

FIGURE 2.1

More complicated FPIF arrangements may have more than one share ratio, but for simplicity reasons, this paper concentrates on the basic FPIF contract shown in Figure 2.1. In this example, both parties share the costs if actual costs are below PTA (\$210,000). If the seller underruns (costs below target costs) the seller earns a profit greater than

the target profit. For example, at an actual cost of \$180,000 the contractor would earn a profit of \$30,000, which is more than the \$20,000 target profit. If the seller overruns, his profits slowly diminish, but the buyer also bears his portion of these costs until the point of total assumption. Above PTA the seller bears all additional costs but still earns some profit until he reaches ceiling price. Once above the ceiling price, the seller loses not only profit but other earnings. For example, in Figure 2.1, if the actual cost is \$240,000, the buyer would only pay the \$225,000 ceiling price. The seller would lose \$15,000 on this contract and earn no profit.

For any FPIF arrangement, the seller would like to negotiate an arrangement, that when graphed like Figure 2.1, is as high and far right as possible. If the seller can negotiate a FPIF that when graphed is higher and farther to the right, the seller will increase his profits regardless of the actual costs and further protect himself from an expensive overrun. FPIF contracts with a relatively high cost uncertainty (15% cost variance among competitive proposals) tend to be negotiated in this direction.

The buyer, on the other hand, wants to negotiate an arrangement, that when graphed, would be as low and far left as possible (but not too far that he increases the chances of

the seller defaulting). A FPIF arrangement that when graphed is lower and farther left would limit the costs of the buyer regardless of actual costs. FPIF contracts with relatively low cost uncertainty (10% cost variance) tend to be negotiated in this direction. Within these two objectives is a fair and reasonable FPIF pricing arrangement.

Although there is no simple strategy for developing a FPIF pricing structure, by understanding the incentive arrangement, acquisition planners can make better use of FPIF contracts. A FPIF arrangement can be a means to balance risk between the inherent cost uncertainty, the contractor's incentive to underrun, and the contractor's protection against an overrun. In a FPIF arrangement, the buyer rewards the seller with more profit if the seller is able to control costs (the lower the actual costs upon completion, the higher the contractor's profit). With this information, one might conclude that a FPIF contract is an effective incentive arrangement when the seller is motivated by higher profits and the buyer's objective is to control costs. To reach this conclusion, however, is ignore half of the FPIF arrangement. The other half focuses on cost overruns. A FPIF arrangement also gives the seller limited protection against a cost overrun. Therefore, a FPIF contract would also be an effective incentive arrangement for the risk averse

contractor who does not seek to maximize his profits but rather wants protection against a costly overrun. In the event of an overrun, the buyer carries his share of the overrun, and may end up paying more than he would have paid with a Firm Fixed-Price contract. Therefore, considering both the under and overrun elements, a FPIF contract is an effective incentive arrangement when both parties want to manage and share the inherent cost risk.

A. ADVANTAGES AND DISADVANTAGES

There are three major advantages to a FPIF arrangement. The first advantage is its flexibility in allocating risk between the two contractual parties. Given the inherent uncertainty, the seller is motivated to control cost to earn a higher profit, yet is also protected against limited cost overruns. Essentially, a FPIF arrangement permits both the buyer and seller to share this risk. A higher/lower contractor share ratio puts more/less risk on the contractor. With a FPIF contract, the two parties can negotiate an appropriate share ratio to balance the risk between both parties. Contrarily, with a cost-type contract, the buyer bears the risk. With a fixed-price type contract, the seller carries the burden. [Ref. 14:p. 319]

The second advantage of a FPIF arrangement is that it fosters communication between both parties. In addition to

negotiating just one price, both parties must agree on a target cost, target profit, ceiling price, and share ratio. These additional requirements encourage both parties to communicate their strengths, weaknesses, and concerns. Through this communication each party can appreciate the concerns of the other party, and work together to ensure a successful contract. [Ref. 3:p. 5-32]

Finally, FPIF contracts increase cost awareness and visibility. Since the contractor's final profit is based on her final cost, the contractor is required to keep accountable records. These records will be used to help both parties negotiate a final actual cost which will be used to determine the contractor's final profit. These records help both the seller and buyer with cost control, cost management, and contract administration. [Ref. 3:p. 5-32] Furthermore, these records can also help both the buyer and seller price future contracts.

FPIF contracts, however, are not without their disadvantages. Two major disadvantages of a FPIF type pricing arrangement are the increased bureaucracy in administering a FPIF contract and potential complications from contract changes. [Ref. 3:p. 5-32] A FPIF contract, given the cost visibility, is much more difficult and expensive to administer than a Firm Fixed-Price (FFP)

contract. Since the Government has no visibility of the actual contract costs with FFP contracts, neither the Government nor contractor needs to keep detailed records. [Ref. 3:p. 5-32] However, with a FPIF contract, both parties must dedicate personnel to ensure an accurate record and analysis of the contract costs. This increases the cost of overhead and, eventually, the final contract price. [Ref. 3:p. 5-32]

A second major disadvantage of a FPIF type contract is negotiating contract changes. [Ref. 3:p. 5-32] Contract changes may require extensive adjustments to existing sensitive pricing agreements. If the Government directs the contractor to make changes in the contract, it is often difficult to equitably quantify the changes into a new pricing structure. Obviously, changes affect the contract and may affect the target cost, target profit, share ratio, PTA, or ceiling price. Both parties must negotiate these changes which can be difficult especially for a terminated contract or a contract in a declining budget environment. These difficulties can lead to a negotiation impasse, adverse relationship, or legal dispute. [Ref. 3:p. 5-32] Regardless of these disadvantages, if used correctly, FPIF contracts are a valuable asset for a contracting officer to balance risk and manage contract performance.

B . FIXED-PRICE-INCENTIVE-FIRM ANALYSIS

One common misconception regarding the FPIF contract is that its primary purpose is to motivate (incentivize) the contractor to control costs. True, a FPIF arrangement encourages the contractor to underrun costs, but not as much as a Firm Fixed-Price (FFP). With a FFP contract, for every underrun dollar, the contractor earns a full additional dollar of profit, and does not have to share the savings with the buyer. With a FPIF contract, the contractor would have to share this savings with the Government. To motivate a seller to underrun costs, basic incentive theory contends that the higher the contractor share ratio, the greater the contractor's motivation to underrun costs. In November 1987, the General Accounting Office (GAO) issued a report on Fixed-Price-Incentive contracts. Regarding contractor motivation, they wrote:

If the contracts act according to incentive theory, we would expect to find ... an increasing tendency for final prices to underrun the target price (or for overruns to be minimized) as the contractor share ratios increase.
[Ref. 7:p. 2]

To test their hypothesis, GAO audited 537 FPI contracts awarded between 1977-1984. GAO compared the actual costs of the contracts (as a percentage of target costs) against the negotiated share ratio. The agency expected to find that the

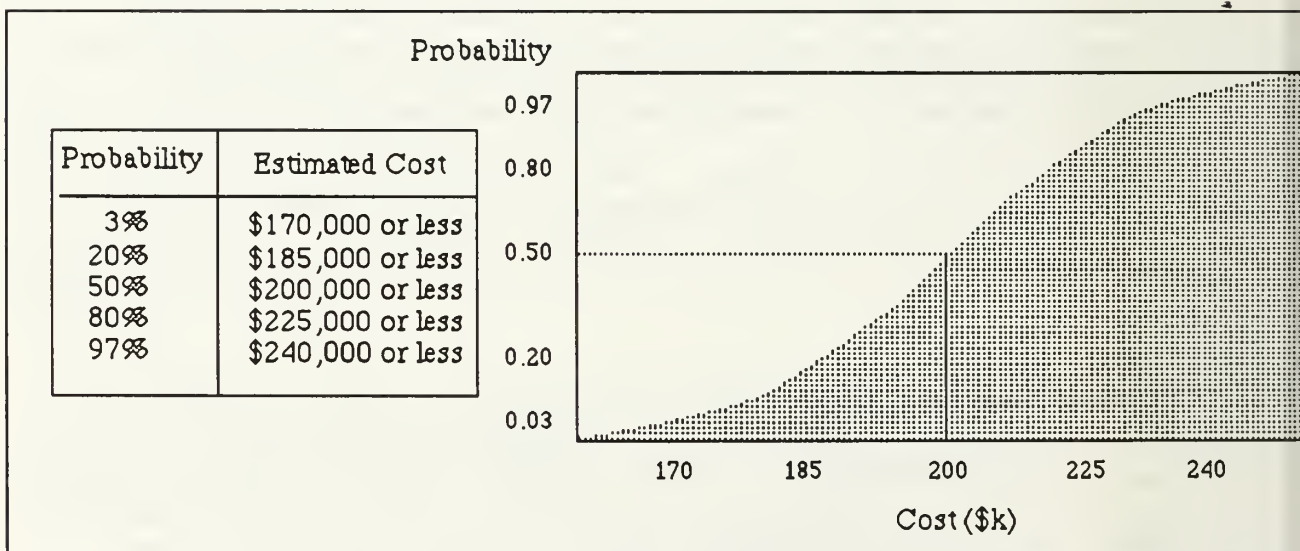
higher the contractor share ratio, the greater the tendency for the actual cost to be lower as a percentage of target costs. In other words, assuming a contractor wanted to maximize her profit, she would work harder to control costs for contracts with a higher share ratio. However, the GAO study found no such correlation; and, GAO erroneously concluded that a higher contractor share ratio has no effect on actual costs.¹ Despite its apparent failure to motivate the contractor in full accordance with incentive theory, GAO acknowledged the value of FPI pricing arrangements. The report concluded:

Although the FPI contracts we reviewed did not behave exactly as the theory predicted, they offer the Government the advantages of being able to limit its financial liability and to share risks with contractors. [Ref.7:p. 4]

These results are often interpreted to mean that a FPIF contract is not a motivator for contractors to control costs,

1. Since the contractor has significant input into the negotiated parameters of the contract, GAO's conclusion is fallacious. A company will negotiate a share ratio, target cost, and other parameters based on the contract's cost uncertainties and the degree of risk the company is willing to accept. In other words, the company that agrees to the higher contractor share ratio has already factored in his risks and cost uncertainties. One way GAO's conclusion would be valid is if all the FPIF arrangements randomly assigned share ratios with no contractor input. Then, under these conditions, and only under these conditions, should the GAO expect to find an "increasing tendency for final prices to underrun the target price (or for overruns to be minimized) as contractor share ratios increase."

but a means for the buyer and seller to balance the cost uncertainty. As discussed in the footnote, this conclusion is incomplete. However, to develop the model, the researcher assumed that GAO's conclusion is accurate within certain parameters. To explain this concept from GAO's perspective, let us revisit the hypothetical contract in Figure 2.1. After reviewing the request for proposal, the contractor will formulate a table or graph representing the probability of cost distribution. If not a formal report, this will be a subjective analysis by top management. One possible presentation of the data is shown in Figure 2.2.



Source: Developed by researcher

FIGURE 2.2

Given this cost uncertainty, a FFP contract would be too risky for the contractor, unless she charged a premium price.

Similarly, the cost uncertainty is not so great that it warrants a cost-type contract. A logical alternative is a FPIF arrangement. Figure 2.2 diagrams the contractor's estimated probabilities of what it will cost to complete this contract. In this example, the contractor estimates that there is a 0.50 probability that she can complete this contract for \$200,000 or less. Each of these probability costs are based on the contractor doing her "best efforts" and have little apparent relation to the contractor's negotiated share ratio. However, in developing this probability cost estimation, the contractor has already factored in an expected share ratio. As long as the negotiated share ratio is near what she expected, her estimated probability of cost distribution (Figure 2.2) will remain the same. However, if there is a significant change in the share ratio, her probability of cost distribution will also change. The researcher's model allows for moderate changes in the share ratio. The researcher assumes that within these moderate changes, the contractor's cost probability will remain relatively constant. This is particularly true if the negotiated share ratio is stable and predictable for the industry.

III. DEVELOPING THE MODEL: A CONCEPTUAL OVERVIEW

To develop a mathematical model for FPIF contracts, the researcher began by studying the human thought process. After writing a case study (Electronic Testing Corporation Case: Appendix B) the researcher presented the study to the Pricing and Negotiations class at the Naval Postgraduate School. A total of 16 students participated. Working in pairs, students were asked (1) to read the case; (2) to develop a FPIF pricing arrangement including target cost, target profit, share ratio, point of total assumption, and ceiling price; and (3) to describe how they approached the issues and reached their conclusions. Hoping to mathematically mimic a business strategy, the researcher was more interested in the students' thought process than the actual results.

The case study describes a hypothetical company in the electronic testing industry. In the case, Electronic Testing Corporation (ETC) is planning to use a FPIF contract to buy new test equipment. The company solicits quotations from various contractors. Eight companies submit quotations. ETC contracting personnel analyze these quotations and assess the reliability of each proposal based on the cost data and past

performance of the contractor. Naturally, some quotations are more reliable than others. ETC also initiates an independent cost estimate. The case portrays the electronic testing business environment, the central issues, the primary concerns of both parties, and historical data on past contracts.

This chapter analyzes the students' approaches in the Electronic Testing Corporation case study and compares their approach to that of the proposed mathematical model. As you will see, the human and mathematical approaches are quite different, as one would expect given the vastly different resources each method uses. The focus of this chapter is limited to the conceptual similarities and differences between the two approaches. Chapter IV will focus more on the mathematics and technical approaches.

A. THE STUDENTS' APPROACH

A definitive pattern developed in the students' approaches toward most aspects of the FPIF contract. To determine the target cost, all students did some type of averaging of the competing proposals. Some groups averaged only the most reliable proposals. Other groups averaged only the low-to-mid range cost proposals. Still other groups averaged only the most reliable proposals then adjusted the result. All

groups used the independent cost estimate either as a check and balance or as an additional proposal to calculate in the average. To determine the target profit, the students started with the historical data, then adjusted these rates based on the specific risk elements of the ETC contract. Although the rates varied between 10-15%, each group justified their rate with the historical data. To determine the ceiling price, most students took a percentage of the target costs. Although no group explained how they chose their percentage, the percentages varied between 115-120% of target cost. The point of total assumption was determined from a mathematical formula based on the ceiling price. Surprisingly, all groups determined the ceiling price first, then used the ceiling price to determine the PTA. And finally, there was no consensus on how to determine the contractor share ratio. The share ratios varied substantially among all groups, from 0.15 to 0.50. Some groups chose different share ratios above and below the target cost. Others just randomly selected a "middle" share ratio, 0.25. A summary of the students' FPIF approaches is shown in Table 3.1.

Some elements of the student thought process summarized in Table 3.1 is not unlike business practices in contracting offices today. The Assistant Secretary of the Navy for

Research, Development and Acquisition, the Honorable Gerald A. Cann, recently published a memorandum regarding the implementation of phased pricing. [Ref. 10:p. 3] Phased pricing is a contracting practice in which the buying office establishes an option for initial production during an engineering and manufacturing development contract. The guidelines suggest a FPIS contract type, that may be modified within parameters, and eventually will be solidified into a FPIF contract. To determine a PTA, the guidelines suggest that the PTA be within the range of 125%-135% of the target cost. The phased pricing guidelines and the students' approach are similar in that both use a percentage of target cost to determine either the PTA or the ceiling price.

TABLE 3.1 STUDENT THOUGHT PROCESS IN DEVELOPING FPIF

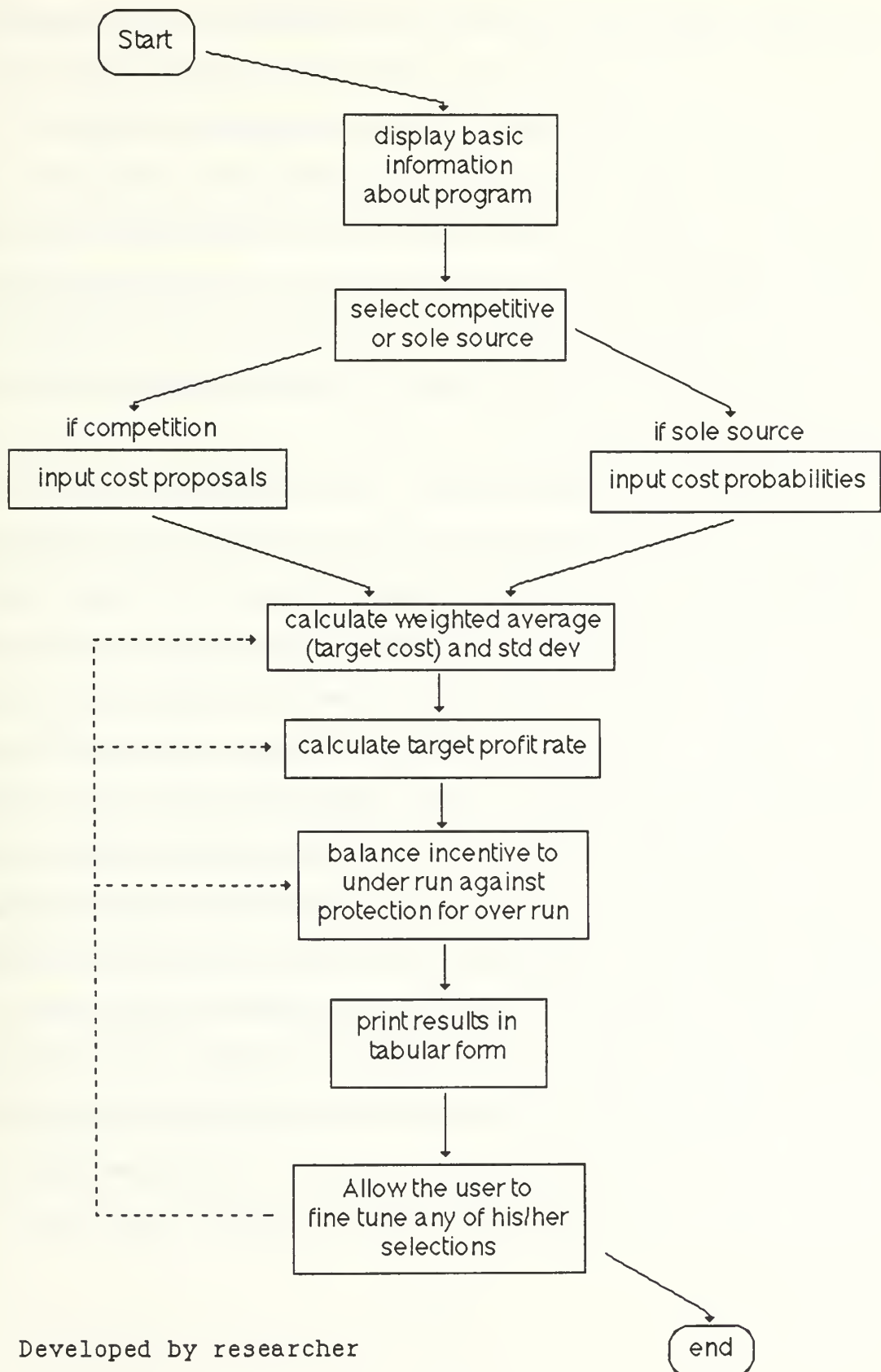
FPIF Element	Student Thought Process and Strategy
Target Cost	some average of proposals
Target Profit	adjusted, historical data
Ceiling Price	some percentage of target cost
PTA	mathematical formula, based on ceiling price
Share Ratio	random

Source: Developed by researcher

B. THE MATHEMATICAL MODEL'S APPROACH

An overview of the computer model is shown in Figure 3.1. This diagram flowcharts the structure and precedence of procedures that the program executes to reach its results. Both the mathematical model and the students' approach have many similarities, but also key differences. The researcher's mathematical model, like the students', begins by first determining a target cost. In competition the target cost is based on the proposals of all contractors in the competitive range. Those proposals deemed the most reliable by the user are weighted more heavily than those proposals deemed less reliable. Reliability is based on the user's assessment of the accuracy of the contractor's cost proposal. A company that bids relatively high for a contract (even though it may have only a slim chance of winning the award) might earn a high reliability factor if it (1) has a history of submitting accurate proposals (2) has the capital and personnel resources, and (3) has the required technical ability for the contract. Based on the cost proposals and the reliability assessment of the user, the model calculates a weighted average, which will be used as the target cost. The entire process is very similar to the students' approach in the Electronic Testing Corporation case. Several students, for example, averaged the most reliable contract

FIGURE 3.1 COMPUTER MODEL FLOWCHART



Source: Developed by researcher

proposals, then adjusted the result based on some subjective analysis, to determine their target cost. The mathematical model, similarly, uses data from all proposals in the competitive range, but assigns more weight to the more reliable proposals. Essentially, the two approaches are very similar except that the students rely on limited analytical data (only evaluating some of the proposals) plus subjective analysis, whereas the model uses all of the proposals but lacks subjective input.

Likewise, both the students' and mathematical model's approach to determining the profit are similar. The model determines the target profit based on historical data. The model allows the user to input the target profit rate two ways. First, the user can input a rate directly, such as 10%. Second, the computer can ask the user a battery of risk questions and calculate a profit rate. The profit rate will be within a preset range (determined by the user based on industry standards). If the user answers the questions that suggest high risk, the profit rate will lean toward the upper limit in the range. If the user's responses suggest low risk, the profit rate will be toward the lower limit in the range. The students, likewise, based their profit on their assessment of risk--the greater the risk, the higher the profit rates. For the target profit, overall, both the

student and mathematical model approaches are very similar. But this is where all similarities cease.

In the next step the model takes more than just a procedural, but a philosophical difference to the student approach. The model builds from three assumptions. (1) The weighted average is the expected cost of the industry (2) The Government is contracting with a "average" company in the industry (3) the cost distribution within ± 3 standard deviations is uniform. The first assumption is based on the market forces of competition. The collective results of these proposals may be compiled to represent the cost curves for the industry, if the industry is homogenous. The second assumption is based on the Government's social-economic programs. Generally, a buyer will tend to select the best, or at least above average, supplier. However, unlike a typical buyer, the Government often has secondary objectives. These secondary objectives might be (1) to develop the industrial base (second or dual sourcing), or (2) to support a social-economical program. As a result, this model assumes the Government is negotiating with an "average" firm whose cost curves are similar to that of the industry's. The third assumption, as discussed in Chapter I, is chosen for its computational ease.

Diverging from the students' approach, next, the model calculates the point of total assumption and the share ratio simultaneously. The computer presents a seven option menu that prompts the user to balance the contractor's risk. Five of the seven options are called 'Normal Pricing' arrangements (only one share ratio). The other two options are called 'Special Pricing' arrangements (different share ratios above and below target costs). The model views these options as a trade-off with no preference for any of the selections. Unlike the students who are employing a subjective strategy in their FPIF, the model prepares five basic options covering a wide variety of share ratios and PTAs. Although each option presents the user with a uniquely different FPIF, all of the options have two key similarities. One similarity is that the area under each of the FPIF curves is the same, which means the expected profit for each curve is identical. The second similarity is that, assuming a uniform cost distribution, the expected cost to the Government for each option is identical and equal to the sum of the target cost plus the target profit. With this arrangement the model attempts to accommodate the contractor based on her attitude toward risk. If the contractor is risk aggressive, she will tend to select the lower options which can offer high rewards, but also heavy penalties for an over run. If the

contractor is risk averse, she will tend to select the higher options which do not offer high rewards, but neither heavy penalties. If the contractor is risk neutral, she will not care which option he selects since the expected profit for each option is identical. Likewise, the Government is indifferent since the expected cost to the Government is the same for each option.

The basic five options, the heart of the model, ask the user to balance the contractor's incentive to underrun against the contractor's protection against an overrun. If the user chooses to incentivize the contractor to underrun, then the model will select a high contractor share ratio (0.50), but a "strict" point of total assumption (+0.5 standard deviation from the target cost). If the user chooses to protect the contractor from an overrun, then the model will select a low contractor share ratio (0.10), but a "loose" point of total assumption (+2.5 standard deviations from the target cost). Obviously, there are several intermediate options between these two extremes.

This approach differs substantially from the student responses in four ways. First, the students' developed only one FPIF curve, whereas the model presents five options to the user. Second, to determine cost and profit rates, the students focus on reasonableness, whereas the model

concentrates on expected profit and expected cost to the Government. Third, the students base the ceiling price on a percentage of target costs, whereas the model bases the PTA on standard deviations. Fourth, the students select share ratio and PTA in two distinct steps, whereas the model selects both simultaneously. Each of these differences is analyzed in the following paragraphs.

While developing their FPIF curves, the students focused on one arrangement only. Each group employed a uniquely different strategy and weaved that strategy into their FPIF curve. The model, on the other hand, attempts to take into account the contractor's attitude toward risk. Based on the contractor's attitude toward risk, the contractor can select from different options. The students focused on their objectives, whereas the model is much more accommodating to the needs of the contractor.

Similarly, when analyzing costs and profit rates, the students tend to assess their FPIF arrangement based on what is reasonable. After selecting each of the unique characteristics (target cost, profit, share ratio, ceiling price) the students ensure that their arrangement is reasonable and fits into their overall strategy. The model makes no assessment of what is reasonable. Instead, it focuses on the expected profit and expected cost to the

Government. For each option, both the expected profit to the contractor and the expected cost to the Government is the same.

The student groups chose the ceiling price based on a percentage of the target costs. This process works well for people because of its mathematical simplicity. It is very easy to calculate a percentage of another number. In the Electronic Testing Corporation case, the students subjectively assess the risk and can manipulate the ceiling price. In this example, the students' responses varied from 115% to 120% of the target cost. The computer model, on the other hand, does not have access to subjective or intuitive information. Instead, it relies on its analytical abilities, namely, rapid mathematical processing. Using the information on the competitive proposals, the program calculates the standard deviation. The point of total assumption is then based on the standard deviation.

The fourth difference between the two approaches is the number of steps used to determine the ceiling price and share ratio. The human thought process used two distinct steps. Again, this procedure is better suited for people because of their abundance of subjective input. The students evaluated risk at every decision point. Given a higher risk, the human thought process might increase profit, extend the PTA and

ceiling price, and evaluate a share ratio based on a subjective strategy. The computer, on the other hand, must be logical and procedural. This model evaluates risk only when calculating the profit rate. When selecting a share ratio and point of total assumption, the mathematical model does not evaluate risk, but only attempts to balance risk. The mathematical model offers the user a trade-off between (1) a strong incentive to underrun and (2) protection against an overrun. The user selects his choice from a menu. As he chooses to increase the contractor's incentive to underrun (higher contractor share ratio), he automatically decreases the contractor's protection against an overrun (lower PTA).

To conclude, Table 3.2 highlights the differences between the human and computer approaches to developing a FPIF arrangement. In some areas both the human and computer approaches are very similar, while other areas are quite different. Regardless of the differences, each method attempts to capitalize on their relative strengths and minimize their weaknesses to develop an effective pricing arrangement, fair to both parties.

TABLE 3.2 DIFFERENCES BETWEEN HUMAN AND COMPUTER APPROACH

FPIF Element	Student Thought Process & Strategy	Computer / Mathematical Approach
Target Cost	some average of proposals	weighted average
Target Profit	adjusted, historical data	user input industry stds / risk adjusted
Ceiling Price	some percentage of target cost	based on PTA
PTA	math formula, based on ceiling price	} determined together based on std dev and risk trade-offs such that expected profit = constant and expected cost to govt = constant
Share Ratio	random	

Source: Developed by researcher

C. THE MODEL'S APPROACH TOWARD A SOLE SOURCE

Finally, since all contracts are not competitive, the researcher modified the program so that it can analyze sole source contracts. For a sole source contract, the user must input 5 probability costs. These are the 3%, 20%, 50%, 80%, and 97% probability costs. The 20% probability cost, for example, is that cost for which there is a 20% probability that the contractor will complete the contract for this costs or less. For the sole source contract, the target cost is the 50% probability cost. Each of the remaining required probability costs are based on standard deviations of a normal distribution. For example, the 20% probability cost is -1 standard deviation from the average. Likewise, the 3% probability cost is approximately -2 standard deviations from

the average. Having calculated the target cost, the model proceeds as describe above by first determining the profit, then balancing the share ratio and point of total assumption. The following chapter describes in detail both the model's competitive and sole source procedures by stepping through an example and explaining the mathematical process at each step.

IV. THE MATHEMATICAL MODEL: A DETAILED ANALYSIS

This chapter focuses on the specific mathematics of the model. The chapter is divided into sections that each discuss the primary procedures of the computer program. These sections are: Calculating the Target Cost, Calculating the Target Profit, Determining the Share Ratio and Point of Total Assumption, Calculating the Option Coefficients, Analyzing the Expected Profit and Government Cost, Understanding the Contractor's Utility, Using Statistics, Analyzing Sole Source Contracts, and Summary. To explain the mathematics, this chapter uses both examples and mathematical derivations. The researcher assumes the reader is familiar with the fundamentals of integral Calculus and Statistics.

A. CALCULATING THE TARGET COST

To calculate the target cost, the model requires the user to first assess the reliability of all bottom-line cost proposals and independent cost estimates, then enter these data in order of most to least reliable into the program. Those cost proposals/cost estimates deemed the most reliable should be entered first. Those deemed less reliable should be entered last. Those proposals outside the competitive range, having no reasonable possibility of winning the award,

should not be entered at all. This information will be used to calculate a weighted average which eventually will be the target cost.

The primary reason the researcher decided to use this prioritized system to calculate a weighted average as opposed to a conventional grading system is to facilitate a user friendly program. With a conventional grading system, the user would have to input each cost proposal then assign a numeric reliability factor to each proposal. These numbers would be highly subjective and the additional qualitative analysis that could be studied would not be that valuable. The prioritized system, although sacrificing some qualitative precision, facilitates a user friendly environment that does not overload the user with cumbersome data entry requirements.

The most common procedure to calculate a weighted average is for the user to assign a "weight" to each data point compared against some standard. For example, if a woman is going to invest in the stock market, she might assign a weight to each possible investment opportunity. For aggressive growth stocks, she might expect a 25% return; for a balanced portfolio of stock she might expect a moderate 12% return; and with a conservative portfolio in U.S. Government Treasury Notes, she might expect an even lower yield of 8%.

By selecting a mixture of these investment strategies, she can calculate a weighted average based on the percentage she invests in each category. Although this procedure for calculating a weighted average is common, it is also tedious and contrary to the manner in which many people make decisions. Knowing the subjective nature of evaluating competitive alternatives, few people want to assign weights to their different options. Another approach to calculating a weighted average is to prioritize a list from best to worst based on some standard criteria. In this method, weights would automatically be assigned based on each item's position in the prioritized list. For example, assume the same woman plans to invest capital in a wide variety of business ventures. She subjectively forms a list in her mind, ranking each investment opportunity from most to least risky. Her list is as follows: high yield junk bonds; Latin America and Pacific Rim industrial stocks; U.S. aggressive growth stocks; short term high grade U.S. bonds; long term European investment grade bonds; home mortgage loans; U.S. Treasury Notes. By automatically weighting the riskier investments heavier than the less risky investments, one can calculate a weighted average through this prioritized list. The advantage of this system is that it does not require the user to assign weights for each investment. Instead, the user need

only prioritize the list. The disadvantage of this system is that it prevents the user from assigning a specific weight to any one of the investments. As human beings, it is natural for us to develop prioritized rankings. We rank everything in our society from Fortune 500 companies to sports teams to academic standings. Thus, to facilitate a user friendly program, the researcher decided to use the prioritized method rather than the grading method.

In the model, the user must prioritize all of the competitive proposals from best to worst based on reliability. The model uses this prioritized list to determine a weighted average by assigning heavier weights to the more reliable proposals based on the following equation:

EQUATION 4.1:

$$\text{Wt Avg} = \frac{n(1\text{st}) + (n-1)(2\text{nd}) + (n-2)(3\text{rd}) + \dots + (n-(n-1))(n\text{th})}{n + (n-1) + (n-2) + (n-3) + \dots + (n-(n-1))}$$

n = total # of cost proposals/est in competitive range
 1st = most reliable
 2nd = second most reliable, etc.

Although this formula may seem extremely complex, in practice it is relative simple. For example, let us examine a hypothetical contract with five competitive proposals as follows:

\$2,000,000	most reliable
\$1,925,000	2nd most reliable
\$1,950,000	3rd most reliable
\$1,975,000	4th most reliable
\$2,025,000	5th most reliable

From Equation 4.1 the model would weight the first cost proposal five times heavier than the last. The second would be weighted four times heavier than the last. The same pattern would continue until all five proposals were evaluated. Using the above formula, in this example the weighted average would be:

$$\begin{aligned}
 &= \frac{(5)(2M) + (4)(1.925M) + (3)(1.95M) + (2)(1.975M) + (1)(2.025M)}{(5) + (4) + (3) + (2) + (1)} \\
 &= \frac{10M + 7.7M + 5.85M + 3.95M + 2.025M}{15} \\
 &= \frac{29.525M}{15} \\
 &= 1.968333M \text{ or } \$1,968,333
 \end{aligned}$$

This weighted average serves as the initial target cost for the model's FPIF arrangement. From this foundation, the model builds. Later in the program, the user will be able to fine tune these initial calculations according to any special negotiation strategy.

B. CALCULATING THE TARGET PROFIT

After calculating the target cost, the next major building block in the model is determining profit. For a FPIF

contract, profit is a slanted line (Figure 2.1) that varies based on the contractor's actual negotiated costs at completion. The mathematical model uses target profit rate (the profit rate at target cost) as the base for establishing this profit line. There are two methods for the model to determine a target profit rate. The first method, simply, is for the user to directly input a rate such as 10%. In this case, to determine the profit rate, the user should have practical knowledge of similar contracts negotiated under similar conditions. The second method is for the user to input a range of industry standards for profit including the maximum, minimum, and average profit rate for the industry. The upper limit in this range would be the maximum profit for a very high risk contract in the industry based on cost, schedule, and performance. The lower limit, similarly, would be the minimum profit for a very low risk contract. Likewise, the average profit rate would be the baseline for a contract with typical risk. The computer would then ask the user a battery of risk questions, including the user's assessment of technical, cost, and management risk. Based on the user's responses, the computer would calculate a target profit rate. If the responses indicate high risk, then the calculated target profit rate will lean toward the upper limit. Similarly, if the responses indicate low risk, then

the profit rate will lean toward the lower limit. As illustrated in the following example, the mathematics of this procedure are relatively simple, yet the calculations can be tedious, making it an ideal application for a computer. In the battery of risk questions, the computer first instructs the user to allocate risk of the contract among technical, cost, and management. The sum of these three should total 100%. This risk allocation is similar to the Department of Defense's Weighted Guidelines. [Ref. 4:part 215.971-2] For example, if a contract is primarily a technical risk, the user might input:

technical risk	0.60
management risk	0.20
<u>cost risk</u>	<u>0.20</u>
total	1.00

Next the user will input his assessment of the technical, management, and cost risk on a five point descriptive scale: very high risk, above average risk, average risk, below average risk, and very low risk. The computer provides the user with background information for each of these risk types and simple guidelines on evaluating risk in each category. For example, in evaluating cost risk the user should consider (at a minimum) the volatility of materials required, the length of the contract, the extent and price of long lead procurement items, the current state and volatility of

inflation, the required training and time needed to train personnel to work on the contract, the general labor/economic conditions, and the amount of Government financing. After the user has assessed risk for each of the three categories (technical, management, cost), then the model calculates a target profit rate based on the following equation:

EQUATION 4.2

$$\text{Target Profit Rate} = T\% (T_{RF}) + M\% (M_{RF}) + C\% (C_{RF})$$

T% = percentage of risk allocated to Technical
M% = percentage of risk allocated to Management
C% = percentage of risk allocated to Cost
T_{RF} = Technical risk factor
M_{RF} = Management risk factor
C_{RF} = Cost risk factor

Equation 4.2 is relatively simple once one understands what each variable represents. The risk percentages are based on the user's initial allocation of risk among technical, management, and cost. The risk factors are based on the user's answers to the risk questions and the industry profit standards. To determine the risk factor for each category, very high risk is equated to the maximum profit. Above average risk is equated to the mean between the maximum profit and average profit. Average risk is equated to the average profit. Below average risk is equated to the mean

between the average and the minimum profit. And finally, very low risk is equated to the minimum profit. Although tedious, the mathematics are relatively simple. The best way to explain the equation is to walk through a hypothetical example. Assume the user has allocated risk as follows:

technical risk	0.60
management risk	0.20
cost risk	0.20

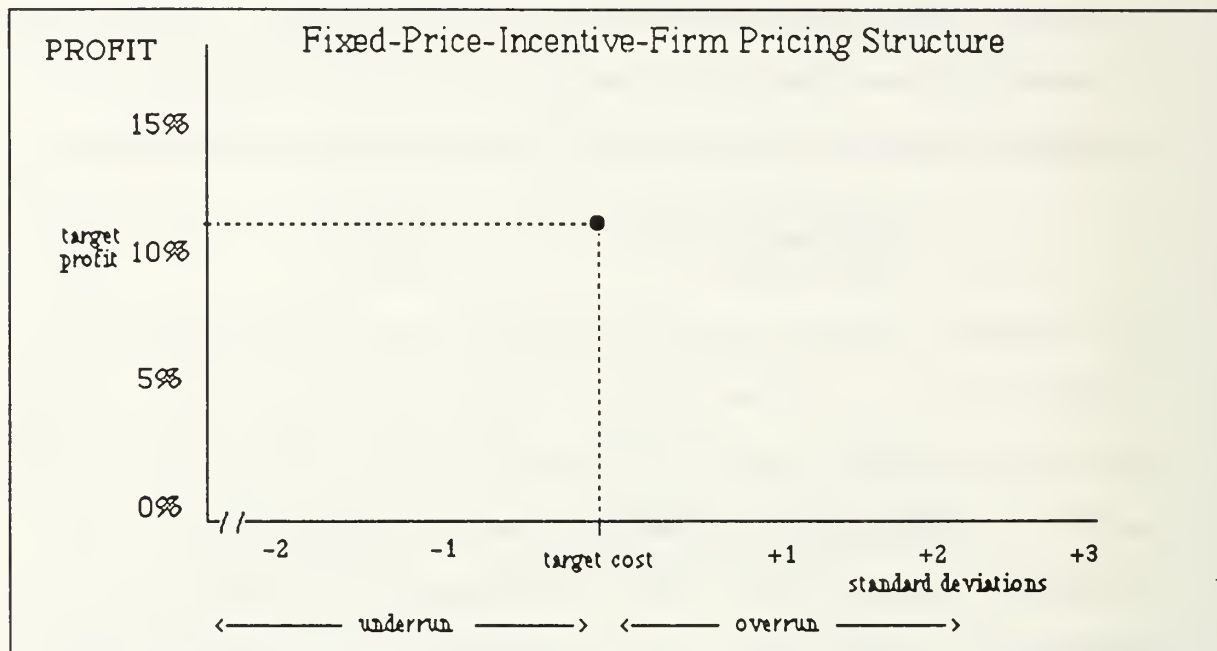
The maximum industry profit is 14%. The minimum industry profit is 7%. And the average industry profit is 11%. The user has assessed that the technical risk of the contract is above average. The management risk of the contract is average. And the cost risk of the contract is very low. Then based on Equation 4.2, the target profit rate would be:

$$\begin{aligned} &= 0.60 ((14\%+7\%)/2) + 0.20 (11\%) + 0.20 (7\%) \\ &= 11.1\% \end{aligned}$$

With the computer model, the user need not be concerned about all of these equations and variables. The model prompts the user for specific information, and the user need only answer the questions.

Now, the skeleton of an FPIF is beginning to form. The model has determined two major elements of the FPIF arrangement--target cost and the target profit rate. If one

were to graph the arrangement with these limited data, it would look like Figure 4.1.



Source: Developed by researcher

FIGURE 4.1

C. THE SHARE RATIO AND POINT OF TOTAL ASSUMPTION

To determine the share ratio and the point of total assumption, the model prompts the user to select from a menu with seven options. The menu is divided into two major sub-categories: normal and special pricing arrangements. The first five options, normal pricing, develop FPIF arrangements with only one share ratio. The last two options, special pricing, result in FPIF arrangements that have different share ratios above and below target costs. Most of the

discussion is limited to the five normal pricing arrangements. Although the program represents the additional options, the mathematical depth of these special pricing options are quite limited, and should not be taken as a serious part of the model. The heart of this model and the discussion that follows is based only on the normal pricing arrangements. The seven option menu presented to the user is shown in Table 4.1.

The first five options, normal pricing arrangements, is the focal point of the mathematical model. This menu gives the user the option to balance the contractor's profit incentive to underrun versus his protection against an overrun. If the user decides to give the contractor a strong incentive to underrun (high share ratio) he will also limit the contractor's protection against an overrun (stricter PTA). This "trade-off" is analogous to the General Accounting Office's study (discussed in Chapter II) that found no correlation between share ratios and final costs. The General Accounting Office concluded that the share ratio was not a significant motivator to control cost, but a means of balancing risk. By giving the user these options, he is forced to "trade-off" or balance one benefit against another.

TABLE 4.1: COMPUTER DISPLAY OF PRICING OPTIONS

Normal Pricing Arrangements:

- 1: pricing arrangement should give maximum profit incentive for contractor to underrun cost in exchange for heavy penalties for an overrun
- 2: pricing arrangement should give strong profit incentive for contractor to underrun cost in exchange for moderate penalties for an overrun
- 3: pricing arrangement should give average profit incentive for the contractor to underrun cost in exchange for some protection against an overrun
- 4: pricing arrangement should give small profit incentive for the contractor to underrun cost in exchange for substantial protection against an overrun
- 5: pricing arrangement should give minimal profit incentive for the contractor to underrun cost in exchange for maximum protection against an overrun

Special Pricing Arrangements:

- 6: pricing arrangement will have different share ratios above & below target cost. The arrangement will give both a strong profit incentive to underrun costs and strong protection against an overrun
- 7: pricing arrangement will have different share ratios above & below target cost. The arrangement will give modest profit incentive to underrun costs and limited protection against an overrun

Source: Developed by researcher

When the user selects an option from the basic five menu, two values are assigned to the FPIF arrangement. First, the user's entry sets the share ratio. Second, it determines the point of total assumption in terms of standard deviations. The first part of this simultaneous assignment is simple to explain. If the user selects option 1, then the contractor share will be the largest (0.50). If the user selects option 2, then the contractor share will be 0.40. The pattern continues, such that if the user selects option 5, then the contractor share will be 0.10. The second part of this dual assignment is more complicated. Unknown to the user, when the model was determining the target cost, it was also calculating a "modified" standard deviation of the competitive cost proposals/estimates. The standard deviation measures variation among data points. The textbook formula for standard deviation is shown in Equation 4.3. [Ref 15:p. 126]

EQUATION 4.3

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^N (n_i - \text{average})^2}{N}}$$

n_i = the individual cost proposals/estimates
average = weighted averaged from EQUATION 4.1
N = total number of proposals/estimates

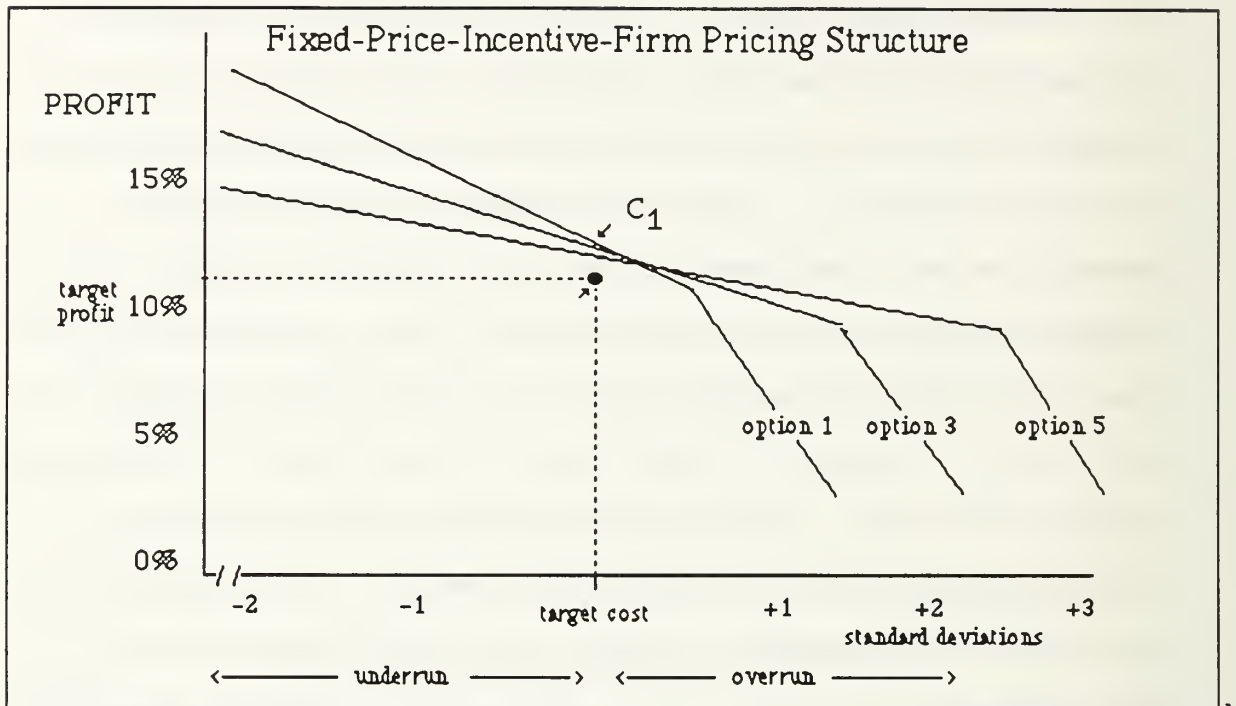
The model calculates a "modified" standard deviation because instead of using the normal average, the model uses the weighted average calculated in Equation 4.1. The results are a slightly greater standard deviation. Although the net effect of the modified calculation is minimal, the researcher chose this approach to allow the model's standard deviation calculation to capture some of the user's reliability assessment.

Having calculated the standard deviation, the model uses this information to determine the point of total assumption. If the user selects option 1, then the PTA is set at +0.5 standard deviation. Option 2 sets the PTA at +1.0 standard deviations. Option 3 sets the PTA at +1.5 standard deviations. Option 4 sets the PTA at +2.0 standard deviations. And option 5 sets the PTA at +2.5 standard deviations. Although not drawn to scale, Figure 4.2 shows the trade-offs between options 1, 3 & 5. Option 1 offers a high profit if the contractor underruns, but also has the least protection against an overrun. Option 5 is the exact opposite.

D. CALCULATING THE OPTION COEFFICIENTS

The researcher selected the different combinations of share ratios and PTAs in order to cover a wide spectrum of options. The contractor's share ranges from 0.10 to 0.50,

and the PTAs range from +0.5 to +2.5 standard deviations. Each of these options were designed to force the user to trade-off between an incentive to underrun versus protection against an overrun. Next, the researcher had to develop a means to ensure that each option was exactly balanced mathematically. In this computation, the researcher assumed that the subjective probability of the contractor's cost distribution remains the same and is independent of the share ratio and the PTA. This assumption must be modified if the contractor can alter the cost distribution. To accomplish this task, the research designed the coefficient options. The coefficient options are coefficients assigned to each option that slightly raise the target profit for that option, such that the area under the FPIF curve for each of the options is identical (Figure 4.2). Notice that for each option the FPIF curve passes slightly above the target profit at the target cost. This difference (distance shown by the arrows in Figure 4.2) is the coefficient for each option. In this case, the distance between the arrows is the coefficient for option 1. Each option has a different coefficient such that the area under each curve within ± 3 standard deviations from the target cost is identical. The five coefficients are: $C_1=0.23958\sigma$; $C_2=0.20000\sigma$; $C_3=0.13125\sigma$; $C_4=0.066667\sigma$; $C_5=0.064583\sigma$, where σ = the standard deviation.



Source: Developed by researcher

FIGURE 4.2

To derive each coefficient, we must find the function that describes the FPIF curve, then integrate over $\pm 3\sigma$. To simplify the mathematics, we translate the y-axis to the target cost, then derive the coefficient for each option. The derivation for C_2 is shown in Equations 4.4 and 4.5.

EQUATION 4.4

$$\begin{aligned}
 f(x) &= -0.4x + C_2 && \text{when } x \leq \text{PTA } (1\sigma) \\
 &= -x + C_2 + 0.6 && \text{when } x > \text{PTA } (1\sigma)
 \end{aligned}$$

First, we describe the FPIF curve for option 2 which has a share ratio of 0.4 and a PTA at 1σ . Equation 4.4 mathematically represents this curve. Next, we integrate the function over the 6σ interval represented by Equation 4.5.

EQUATION 4.5

$$\int_{-3\sigma}^{\sigma} (0.4x + C_2) dx + \int_{\sigma}^{3\sigma} (-x + C_2 + 0.6\sigma) dx = 6\sigma T_{\pi}$$

where T_{π} = target profit
 σ = standard deviation
 C_2 = coefficient for option 2

solving this equation for C_2 we find:

$$-0.2x^2 + C_2 x \Big|_{-3\sigma}^{\sigma} + \left(-\frac{1}{2}x^2 + C_2 x + 0.6x\sigma \right) \Big|_{\sigma}^{3\sigma} = 6\sigma T_{\pi}$$

$$-1.2\sigma^2 + 6C_2\sigma = 6\sigma T_{\pi}$$

$$C_2 = T_{\pi} + 0.2\sigma$$

Thus, the coefficient for option 2 is 0.20σ

The function $f(x)$ mathematically represents the FPIF arrangement (Equation 4.4). The FPIF arrangement can be described as two lines, one when the actual cost (x) is less than PTA, and another when the actual cost is greater than

PTA. Below the PTA, the slope is -0.4 which corresponds to the 0.4 share ratio for option 2. Above PTA, the contractor bears all additional costs representing the -1.0 slope. To solve for C_2 , we integrate over the effective range $(+/- 3 \sigma)$.

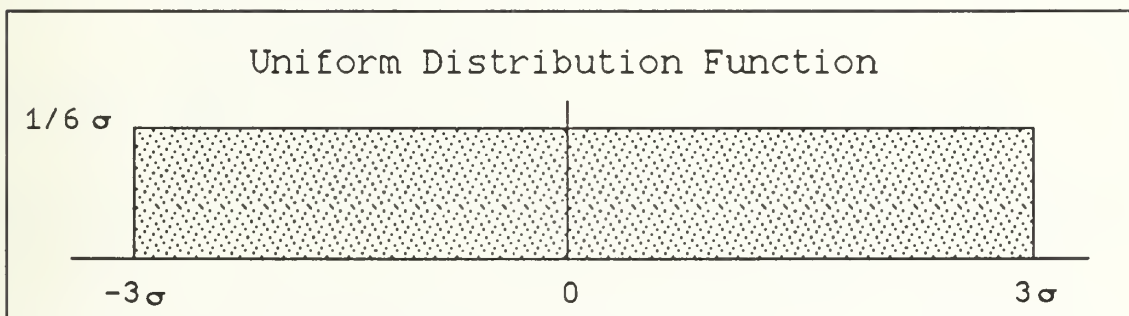
We equate the area under the FPIF curve to $6\sigma T_\pi$, which is the area of a rectangle with base 6σ (interval) times the height T_π (target profit). By applying the same mathematics to the other options, we can find each of the five coefficients such that the area under each curve is identical.

E. ANALYZING THE EXPECTED PROFIT AND GOVERNMENT COST

Equal area for each option is an important aspect of a balanced trade-off. If the areas under each curve are equal, assuming a uniform distribution, then the expected contractor profit for each option is equal. The expected profit would be the area under the curve divided by the interval which the model defines as $+/- 3$ standard deviations. Since the area under each curve is the same, and the interval is the same, the expected profit for each option would be the same.¹

¹. The mathematical derivation to calculate the expected profit for the contractor is identical to the derivation calculating the expected cost to the Government. Instead of showing the derivation twice, the researcher will only show the derivation for the expected cost to the Government.

Next, we analyze the expected cost to the Government. The expected cost to the Government is the sum of the actual negotiated cost at contract completion plus the contractor's profit. To calculate the expected cost, we need a probability cost distribution function. The most realistic probability cost distribution function would be a normal distribution, however, as discussed in the first chapter, to simplify the mathematics, we assume a uniform distribution. A uniform distribution implies: (1) there is 100% probability that the final negotiated cost will be within $\pm 3\sigma$ from the target cost; and (2) within $\pm 3\sigma$, each cost has an equal probability of being the final negotiated cost (Figure 4.3).

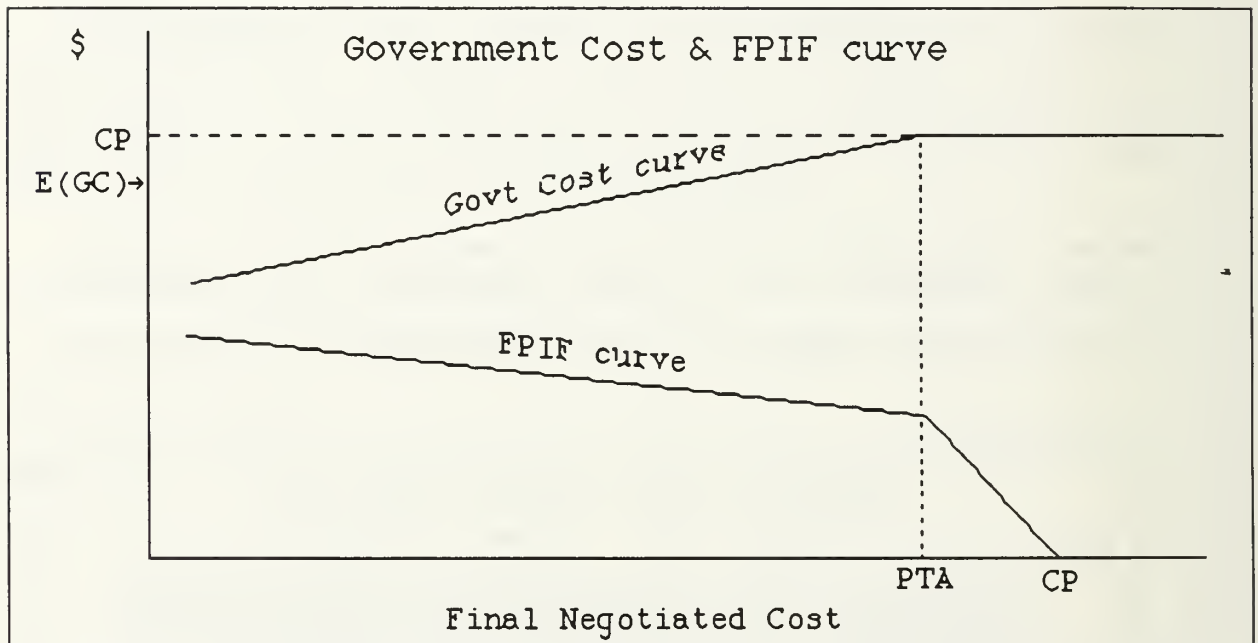


Source: Developed by Researcher

Figure 4.3

To determine the expected Government cost, first we find the function $f(x)$ that represents the Government cost, then integrate over the interval. The Government cost is the sum

of the final negotiated cost plus the contractor's profit. Below PTA, this cost increases as the actual costs increase. Once at PTA, the Government assumes no further responsibility. Each additional cost is assumed by the contractor. Thus, above PTA the cost to the Government is the ceiling price. Graphically, this relationship is shown in Figure 4.4.



Source: Developed by researcher

Figure 4.4

Figure 4.4 shows the Government cost curve transposed above a FPIF curve. The FPIF curve initially has a negative slope equal to the contractor's share ratio. Once the FPIF curve reaches PTA, the slope equals negative one. The Government cost curve initially has a positive slope equal to the

Government's share ratio. Once the Government cost curve reaches PTA, the curve remains flat, equal to the ceiling price. Above PTA, every additional dollar is being paid by the contractor. The Government cost curve shows that the lower the actual costs, the lower the total cost to the Government until PTA. Equation 4.6 mathematically describes the Government cost curve.

EQUATION 4.6

$$\begin{aligned}
 \text{Govt Cost} &= \text{actual cost} + \text{profit} \\
 &= x + s*TC + T_{\pi} - s*x + C_{\text{opt}} \\
 &= s TC + T_{\pi} + C_{\text{opt}} + (1-s)x \quad \left. \vphantom{\begin{aligned} \text{Govt Cost} &= \text{actual cost} + \text{profit} \\ &= x + s*TC + T_{\pi} - s*x + C_{\text{opt}} \end{aligned}} \right\} x \leq \text{PTA} \\
 &= CP + C_{\text{opt}} \quad x > \text{PTA}
 \end{aligned}$$

where

x = actual cost

s = contractor share ratio

TC = target cost

CP = ceiling price

C_{opt} = coefficient for the option selected

T_{π} = target profit

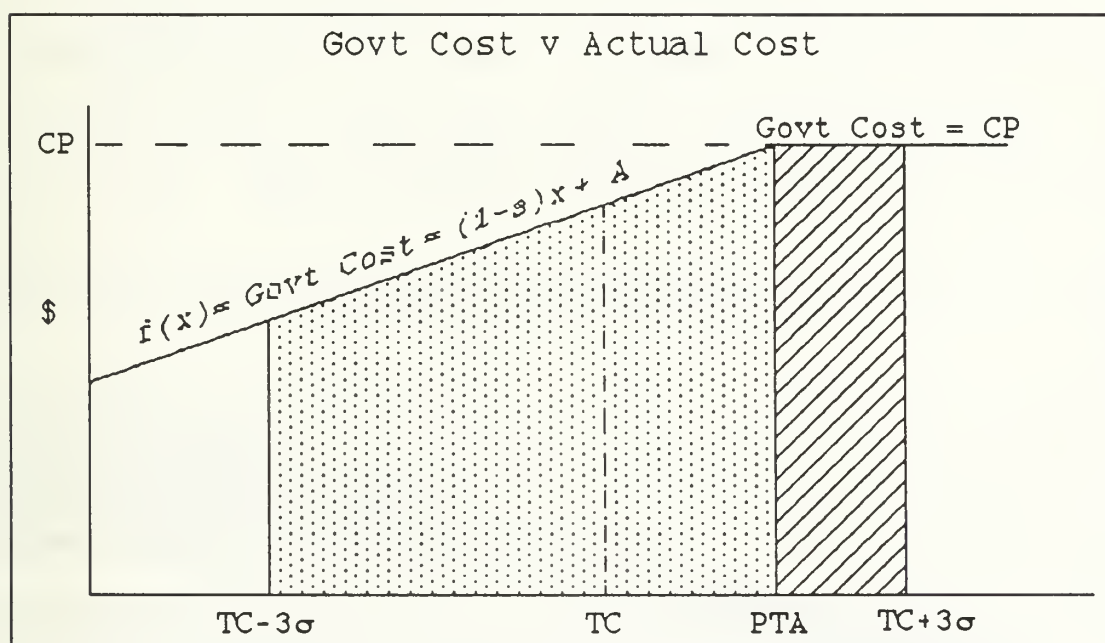
To calculate the expected cost to the Government, one must integrate the Government cost curve (Equation 4.6) over the $\pm 3\sigma$ interval. This relationship is shown in Equation 4.7.

EQUATION 4.7

$$\text{Expected Govt Cost} = \frac{1}{6\sigma} \int_{TC-3\sigma}^{PTA} (s TC + T_{\pi} + C_{opt} + (1-s)x) dx + \frac{1}{6\sigma} \int_{PTA}^{TC+3\sigma} (CP + C_{opt}) dx$$

Mathematically, with all of the symbols, it is difficult to see exactly what is happening in Equation 4.7. Graphically, the picture is much clearer. With a uniform distribution, the expected Government cost (Equation 4.7) is the average of the Government cost evaluated over the interval $(+/- 3\sigma)$. In Figure 4.4 the approximate expected Government cost is designated by $E(GC)$ near the arrow. In the model, since the area under each of the FPIF curves for each option is equal to $6\sigma T_{\pi}$, the expected Government cost for all of the options is also the same. Therefore, regardless of which option the user selects, with a uniform distribution, the expected Government cost for each option is a constant equal to $(TC + T_{\pi})$. To show this relation mathematically, we must complete the complicated integration in Equation 4.7, but a simpler approach is to solve the problem graphically with geometry. The integration in Equation 4.7 is nothing more than computing the area of the Government cost curve, then dividing the area by the interval. The Government cost curve

is Equation 4.6, which graphically looks like Figure 4.5. The integral in Equation 4.7 is nothing more than the sum of the two shaded regions in Figure 4.5. The area of the rectangle on the right is $(TC+3\sigma-PTA)*CP$. The area of the trapezoid on the left is $(f(TC-3\sigma)+CP)/2 * (PTA-(TC-3\sigma))$, where $A = \text{the } x\text{-intercept or } sTC+T\pi+C_{opt}$ and $f(TC-3\sigma)$ is the function $f(x)$ evaluated at $TC-3\sigma$.

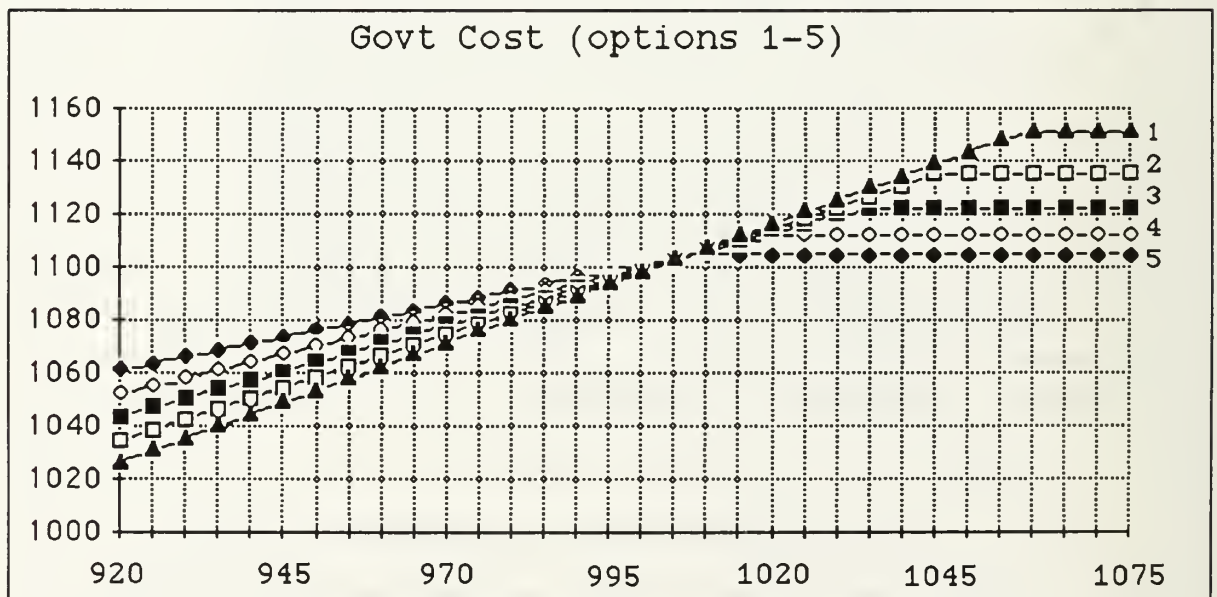


Source: Developed by researcher

Figure 4.5

Next, if one programs these area formulas into a spreadsheet, one can calculate the expected area for any example. First the researcher programmed a spreadsheet in

accordance with these two area formulas. Second, the researcher entered some sample data as competitive proposals into the computer model (\$1000, \$995, \$980, \$975, \$1010, and \$1050) at 10% profit rate. The same data were entered for each of the five options. The computer model calculated the weighted average (\$995) and the target profit (\$100) as well as the share ratio, PTA, and ceiling price for each of the five options. Based on the computer results for each of the five options, the researcher entered the data into a spreadsheet program to graph the Government cost curves for each option with the sample data. The five Government cost curves for each of the options are shown in Figure 4.6.



Source: Developed by researcher

Figure 4.6

Next, with the spreadsheet program, the researcher calculated the area under each curve over the 920 to 1075 interval, then divided by the interval. The result for each curve was identical, \$1095. (Notice how each of the Government cost curves also intersect at that point, \$1095.) These results confirm that the expected cost to the Government is $E(GC) = TC + T_{\pi} = \$995 + \$100 = \$1095$.

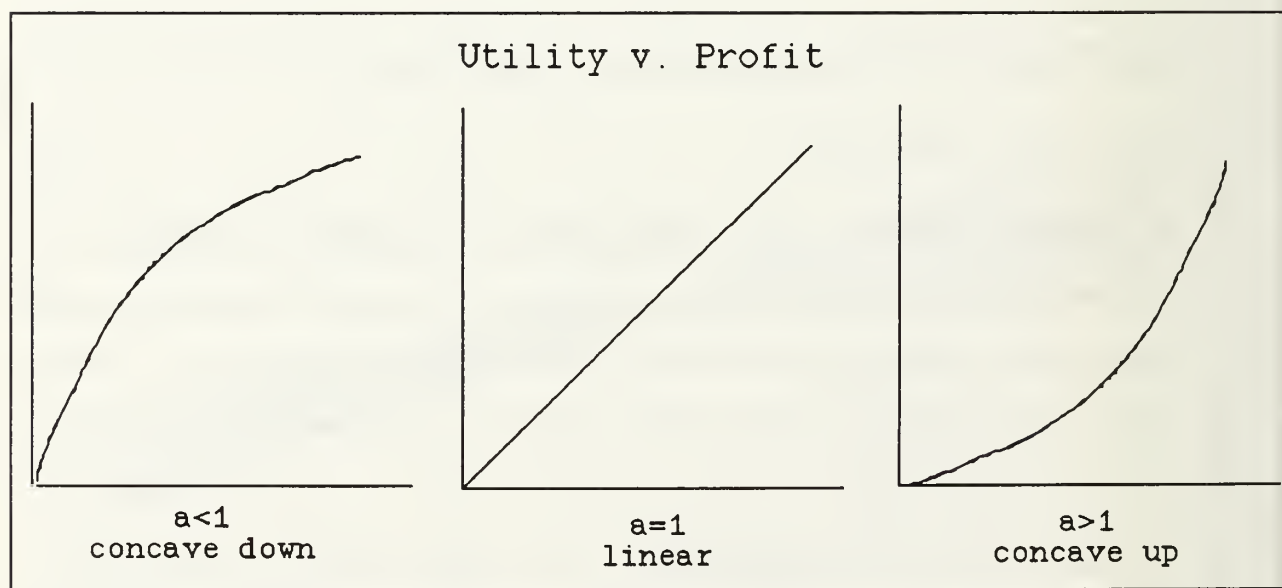
In summary, if we assume a uniform distribution, the model presents the user with five options each with distinct characteristics but an identical expected profit for the contractor and an identical expected total cost to the Government. The Government, therefore, should be indifferent to the option that the contractor prefers. Furthermore, the contractor should select that option which best matches her attitude toward risk.

F. UNDERSTANDING THE CONTRACTOR'S UTILITY FUNCTION

No economic model would be complete without analyzing the expected utility of these options for the contractor. Thus far, the researcher has shown that both the expected profit for the contractor and the expected cost to the Government are constants for each option. But what about the utility function for the contractor? A contractor's utility function is based on his composite attitude toward risk and profit. A

company may be risk averse, neutral, or aggressive. Although most companies tend to be risk averse, the degree to which these companies are risk averse may vary significantly.

The utility function of a company can be represented by the following equation: $U = \pi^a$ (Equation 4.8) [Ref 9:pp. 442-445] If graphed, a utility function can take one of three distinct possibilities, based on the value of a . If $a < 1$, then the utility function will be concave down. If $a = 1$, the utility function will be linear. And if $a > 1$, then the utility function will be concave up. Each of these three possible utility functions are shown in Figure 4.7.



Source: Developed by researcher

Figure 4.7

The left graph, where $a < 1$, implies that the contractor would get more utility out of the first profits and less utility from later profits. The center graph, where $a = 1$, implies that the contractor gets equal utility from each dollar she earns. Finally, the right graph implies that the contractor gets more utility from the last profits earned, than from the initial profits.

The objective of this mathematical analysis is to compare the expected utility of the contractor for each of the five options for each type of utility function. Based on the contractor's utility function, will she tend to prefer one option over the others? To analyze the contractor's preference, one needs to start with the expected utility function.

The expected utility $E(U)$ is defined by the integral of the utility function evaluated over some interval. For the five particular options in this analysis, the expected utility is described in Equation 4.9. As before, the two integrands represent the linear FPIF arrangement. The interval remains the same ($\pm 3\sigma$) as do the upper and lower limits which are $TC + 3\sigma$ and $TC - 3\sigma$ respectively. However, beyond these commonalities, each of the remaining variables change based on the different options. As a result, it is

very difficult to evaluate these integrals in respect to the options represented in the model.

Equation 4.9

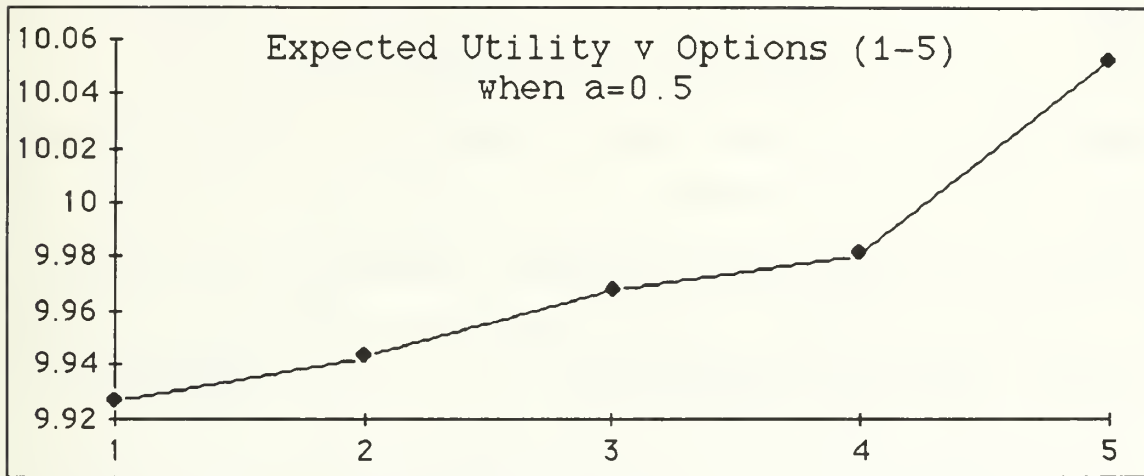
$$\begin{aligned} \text{Expected Utility} &= \frac{1}{d} \int_{PTA}^H (CP + C_{opt} - x)^a dx + \frac{1}{d} \int_L^{PTA} (A + C_{opt} - sx)^a dx \\ &= \left. \frac{-(CP + C_{opt} - x)^{a+1}}{d(a+1)} \right|_{PTA}^H - \left. \frac{(A + C_{opt} - sx)^{a+1}}{ds(a+1)} \right|_L^{PTA} \end{aligned}$$

where

H = higher limit	a = utility exponent
L = lower limit	A = sTC + T _π
d = H-L	all other variables as before

An alternative approach is to look at the same example studied earlier in this chapter. The researcher entered the following competitive proposal data into the computer (\$1000, \$995, \$980, \$975, \$1010, \$1050). For each option, the computer calculated the proposed FPIF pricing arrangement including the share ratio, target cost, target profit, PTA, and ceiling price. The researcher used the results from the computer program in Equation 4.9, then entered the data into a spreadsheet program to graph the expected contractor utility for different values of a. (a=0.5, a=1.0, a=1.5). In the first case, where a=0.5, the researcher found that the expected utility increases as the user selects a higher

option. This relationship is shown in Figure 4.8. In other words, if the contractor is risk averse, she will get the highest utility from option 5.

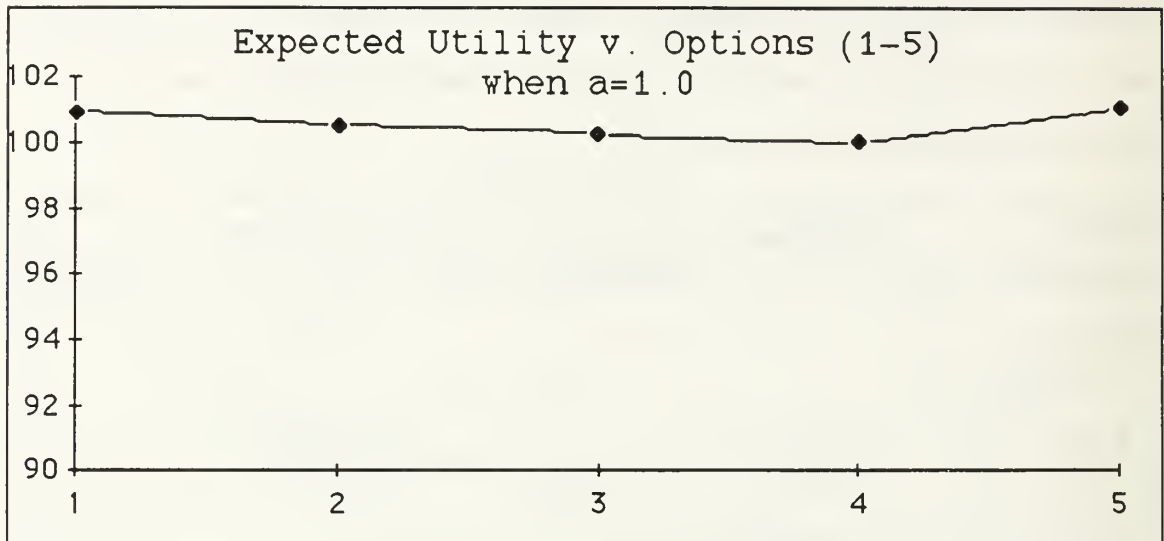


Source: Developed by researcher

Figure 4.8

In the next case, where $a=1.0$, the researcher found that the expected utility for the contractor remained relatively constant (approximately 100 units) for different options as shown in Figure 4.9.² This graph implies that if the contractor is risk neutral, she will be indifferent as to which option she selects. This idea corresponds to the fact that for each option the expected profit to the contractor is the same. If the expected profit is the same, and the contractor is risk neutral, she should be indifferent to all of the options.

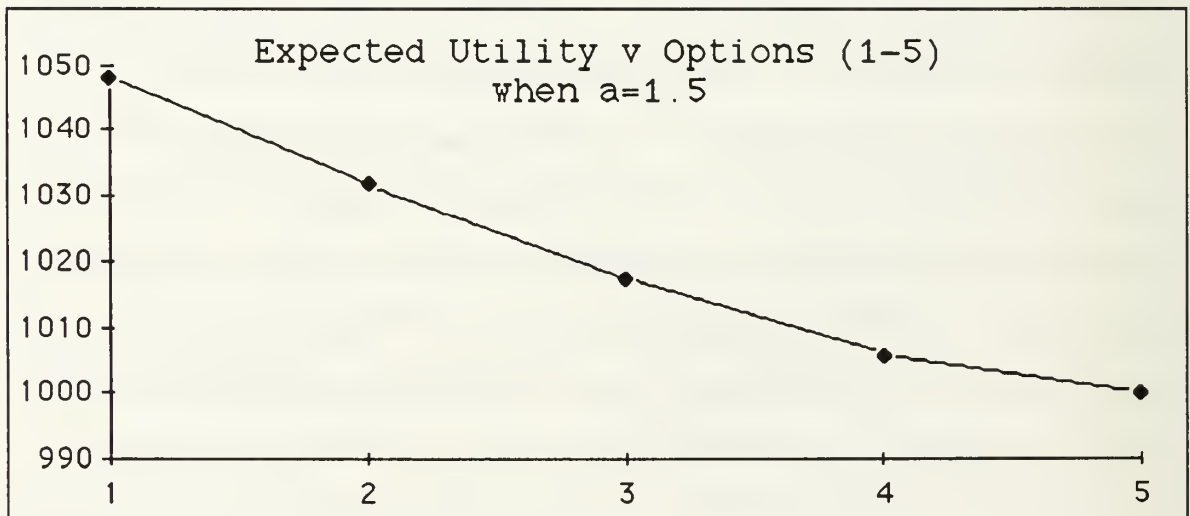
2. Figure 4.9 should be perfectly flat. The slight curve in the graph is due to rounding errors.



Source: Developed by researcher

Figure 4.9

Finally, in the third case, where $a=1.5$, the researcher found that the expected utility for the contractor decreases as the user selects a higher option. (Figure 4.10)



Source: Developed by researcher

Figure 4.10

In this case, the contractor is risk aggressive and would prefer the lower options. The lower options have the highest penalties for cost overruns, but also the greatest rewards for underruns.

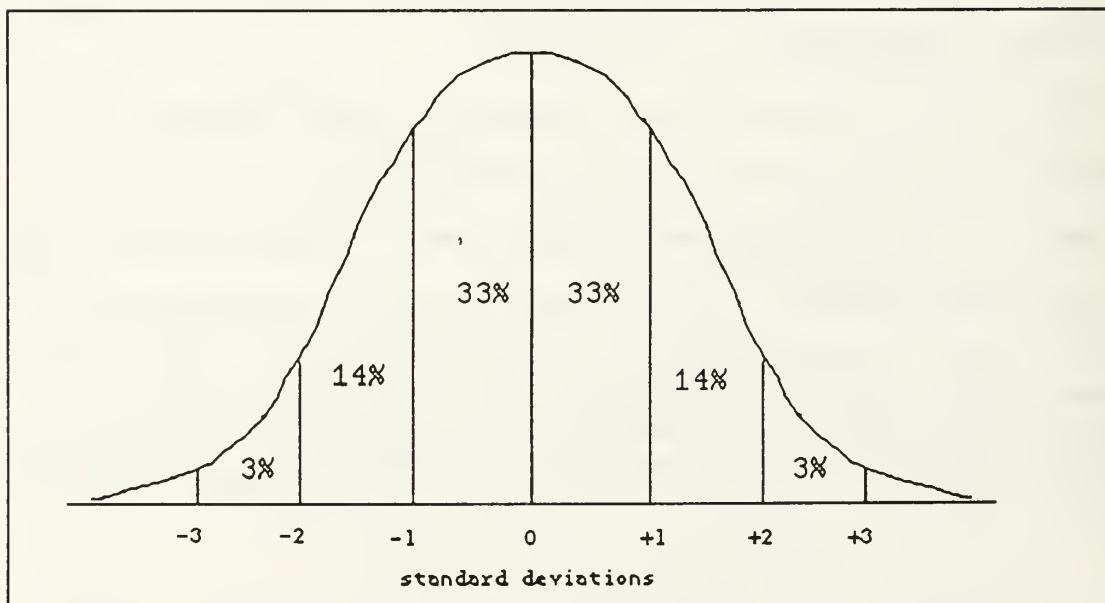
In summary, this model presents the user with five different options. For each of these options, the expected profit for the contractor and the expected cost to the Government are constants. However, contractors do not act solely on the basis of expected profit. Contractors also make decisions based on risk and utility. To maximize the contractor's utility, if the contractor is risk averse, she will tend to select the higher options. If the contractor is risk aggressive, she will tend to select the lower options. If the contractor is risk neutral, she will be indifferent as to which option she selects.

G. USING STATISTICS

Thus far, to simplify the mathematics, the researcher has assumed a uniform distribution. At this point, it would be valuable to shift gears and analyze some of the properties of a normal distribution. In reality, the cost proposals will tend to have a "normal" bell shape distribution. Assuming a "normal" bell shape distribution, the standard deviation

provides a wealth of statistical information. In a normal distribution, one can assume that approximately 68% of the contractors will fall within ± 1 standard deviation, and almost 95% within ± 2 standard deviations. [Ref 15:p. 315] Because this model bases the PTA on standard deviations, this information can provide a wealth of statistical information.

One powerful aspect of a normal distribution is that it allows the user to predict the distribution of cost proposals. (Figure 4.11) From this graph, one can see that only 3% of the proposals will fall above $+2$ standard deviations. Approximately 14% of the proposals will fall between $+1$ and $+2$ standard deviations. And approximately 33% will fall between the average and $+1$ standard deviation. Since a normal distribution is symmetric about the average, the same can be said about the negative standard deviations.



Source: Developed by researcher

Figure 4.11

With this information, assuming (1) a normal distribution; (2) a typical company wins the award; (3) the cost proposals are an accurate reflection of the actual costs; and (4) at least four competitive proposals, then if the user selects, for example, option 2 (which sets the PTA at +1 standard deviation) there is approximately a 17% chance that the actual cost will exceed the PTA (Figure 4.12). Despite the numerous assumptions made to reach this conclusion, these data are valuable as a baseline estimate. The researcher used this baseline information to develop the model. With the same assumptions, for option 1 there is approximately a 30% chance that actual costs will exceed the PTA. For option 2, there is a 17% chance. For option 3 there is a 9% chance. For option 4, there is a 3% chance. And finally, for option 5, there is approximately a 1% chance actual costs will exceed the PTA. Obviously, from the above information one can see that the lower the option, the greater the risk of incurring costs in excess of the PTA. To balance this additional risk, the lower options also have a higher contractor share ratio. As stated before, for option 2 there is a 17% chance that actual costs will exceed the PTA (+1 standard deviation).

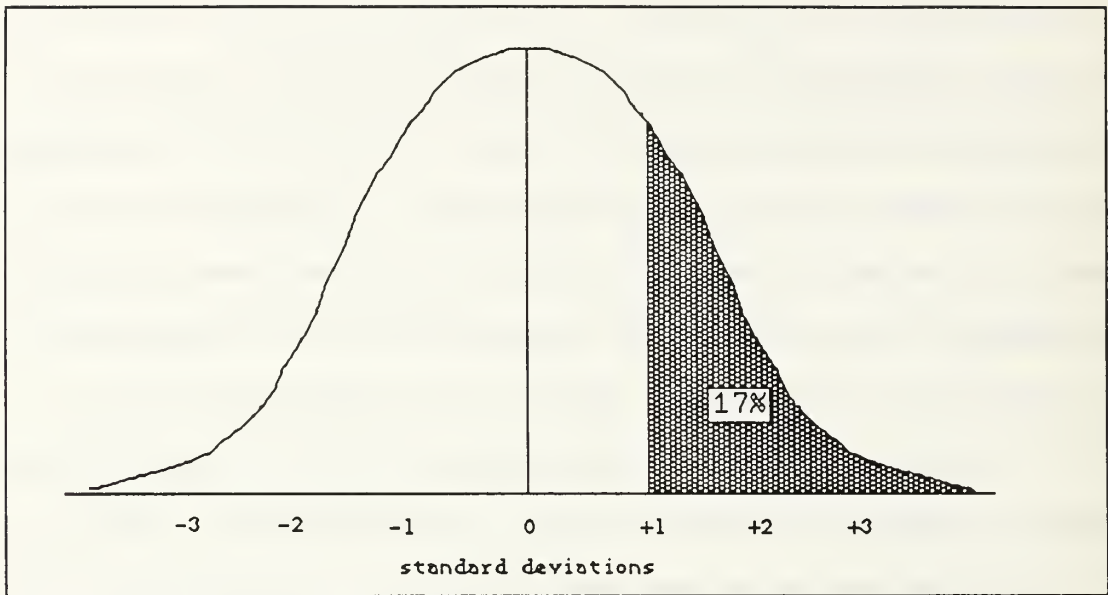


Figure 4.12

However, there is also a 17% chance that the actual costs will be less than -1 standard deviation. Option 2 sets the contractor share at 0.40 (relatively high). If the contractor underruns cost, with the higher share, she will reap a larger profit. Thus, each option is a trade-off between protection against an overrun and incentive to underrun.

H. ANALYZING SOLE SOURCE CASES

Finally, since competition is a luxury that the buyer cannot always obtain, the researched wanted to modify the model so that the user could use the program in a sole source environment. Thus far we have only discussed the competitive

part of the model. In the competitive model, the program calculates a standard deviation for the industry using data points from all proposals/cost estimates in the competitive range. From these data, the model develops a FPIF pricing arrangement targeted toward a typical or average firm in the industry. If negotiating with an industry leader or poor performer, the user can later fine tune the arrangement toward that company's specific needs.

In the sole source arena, without cost proposals from different companies, it is impossible to calculate a standard deviation. Thus, instead, this half of the model attempts to develop the cost curves for this one particular company only. *

For the sole source part of the model, the user must input the 3%, 20%, 50%, 80%, and 97% probability costs for this one particular company only. Obviously, these costs will be estimates and should be based on input from the contractor, cost analyst, negotiator, and any other available source. In theory, given the characteristics of a standard deviation, each of these costs, assuming a normal cost distribution for the company, should be evenly spaced one standard deviation from the next. In other words, the difference between the 97% and 80% cost probability should be the same as the difference between the 80% and 50% cost probabilities. The chance that these costs will be exactly evenly spaced is

remote. To compensate, the model calculates an average which it uses as the standard deviation. Since the data from the user may not translate to a normal curve, the researcher's model "averages" the user's data then forces them into a normal bell shape curve. The disadvantage of this process is obvious: the data are skewed, although the net effect will probably be minimal. The advantage of the process is significant: it allows the user to make full use of a "normal" distribution. This information allows the user to make powerful predictions regarding the possible cost distributions. For example, if the user input the following probability data for a sole source contract:

		differences
3% cost probability	\$1,110,000	
20% cost probability	\$1,190,000	+\$ 80,000
50% cost probability	\$1,250,000	+\$ 60,000
80% cost probability	\$1,300,000	+\$ 50,000
<u>97% cost probability</u>	<u>\$1,400,000</u>	<u>+\$100,000</u>
total		\$290,000
average		\$ 72,500

With these data, by working backwards, the model can calculate a standard deviation. Now this information can be used exactly as if it were part of the competitive model. The weighted average is the 50% cost probability. And the standard deviation is \$72,500. All of the remaining characteristics of the FPIF arrangement are calculated the same way as in the competitive model. Forcing the data into

a normal curve gives the user the same statistical information regarding probabilities of cost overruns as with the competitive model. The only key difference is in the competitive model. The program develops a FPIF arrangement targeted toward a typical company in the industry. For sole source cases, the model focuses on the cost curves of only one particular company.

I. SUMMARY

In summary, to develop a FPIF arrangement, this model starts by calculating the target cost and target profit. Next, the model presents the user with five different FPIF options. Each of these options represents a balanced trade-off. At one extreme, the FPIF arrangement will have a high contractor share (0.50), but a strict PTA ($+0.5\sigma$). At the other extreme, the FPIF arrangement will have a low contractor share (0.10), but a loose PTA ($+2.5\sigma$).

Furthermore, by calculating coefficient options, each option is balanced such that, for each option, both the expected profit for the contractor is the same, and the expected cost to the Government is the same.

V. CONCLUSION, RECOMMENDATION, & FOLLOW-ON RESEARCH

A. CONCLUSION

After analyzing the students' thought process for developing FPIF contracts, the researcher concludes that the unstructured human process relies significantly on personal perceptions and judgment. To balance the human process, the researcher's goal was to develop a mathematical FPIF model that would approach the problem logically and systematically. The model, designed to complement not replace the human approach, has both similarities and differences from its human counterpart. The researcher hopes that this initial research may lead to the further development of mathematical and computer models that will eventually become tools for tomorrow's contracting officers. Using both the model's systematic approach and the user's subjective analysis, the researcher believes that the final result will be a superior product than otherwise would have been developed.

The most significant difference in the model's approach from the students' approach is the concept of a balanced trade-off. The model presents the user with different options that each have the same expected profit for the contractor and the same expected cost to the Government.

Then based on the contractor's attitude toward risk, she can select the option that she prefers. This approach attempts to (1) accommodate the contractor, (2) stabilize the expected Government cost, and (3) be fair and reasonable.

The analysis of the contractor's expected profit and the Government's expected cost is one of the major strengths of this model. When studying the students' approach, the researcher noted that no group analyzed either of these factors. Although just an estimate, both of these estimates help a contracting officer ensure that the arrangement is fair and reasonable. The Government prides itself on its ability to be fair and reasonable. Merely by signing his name, a Government contracting officer implies that the Government is paying a fair and reasonable price. However, in this case, the students made no effort to mathematically estimate either the expected profit for the contractor or the expected cost to the Government.

B. RECOMMENDATIONS

Although the researcher does not propose that this mathematical model be immediately implemented in the contracting community, there are certain properties that this model incorporates that would be beneficial to contracting officers. The researcher's recommendations are that the contracting officer: (1) evaluate the expected cost to the

Government; (2) accommodate the contractor by giving her more flexibility in negotiating "balanced" trade-offs.

The researcher recommends that contracting officers, when constructing a FPIF arrangement, should evaluate the expected cost to the Government. The mathematical model, although only an estimate, attempts to calculate the expected cost to the Government. As protectors of the taxpayer's money, this information is valuable because it ensures that the Government is paying a fair and reasonable price. The current practice only requires that the contracting officer consider the target price. The target price is simply the target cost plus the target profit. Although this represents a "target" or objective, it is in no way related to the expected cost to the Government. On the contrary, the expected Government cost gives the contracting officer much more information. This is the cost, based on all available information, that the Government should expect to pay upon contract completion.

The researcher's second recommendation is that, when constructing a FPIF arrangement, the contracting officer should consider, in addition to his own objectives, the contractor's attitude toward risk. To accomplish this recommendation requires a philosophical change in attitude. For example, the contracting officer might provide more

flexibility to the contractor regarding trade-offs among the share ratio, PTA, and target profit as long as the expected cost to the Government is the same.

C. FOLLOW-ON RESEARCH

There are six areas of possible follow-on research that would be valuable in developing potential software for contracting officers. These areas span a wide variety of expertise--from contracting to mathematics to computer science. They include: (1) a comparison between the final results and the processes of how contracting experts and the researcher's mathematical model develop FPIF arrangements, (2) a derivative model that balances contractor utility rather than the expected cost to the Government, (3) an upgraded model using a normal rather than a uniform distribution, (4) the development of similar models for other contract types, (5) an upgraded version of the researcher's computer program, and (6) an advanced version of the model that treats the cost probability density function parameters as endogenous.

1. Comparing Experts Against the Model

One means for this model to gain credibility is to compare both the results and the processes of how contracting experts and the mathematical model develop FPIF arrangements. The researcher hopes that through further research this model

can be tested against either current FPIF negotiating teams or historical records of FPIF contracts. Furthermore, by analyzing current FPIF practices, lesser developed areas of the model could be updated. The researcher has devoted significant time to studying the mathematics of balancing the different options. This is the cornerstone of the model. However, much less time has been devoted to ensuring an accurate initial assessment of risk (i.e., the initial target profit calculation).

2. A Derivative Model

This mathematical model revolves around the concept of balancing the different options. For each of the five options, the expected cost to the Government is the same. As such, the Government is indifferent to the option that the contractor prefers. Another interesting approach would be to balance the utility of the contractor for each option. To balance the utility for different options, the researcher would have to make an assumption regarding the contractor's attitude toward risk. With this approach the contractor would be indifferent to all of the options, and the Government's objective would be to minimize cost.

3. Using a Normal Distribution

To develop the current model, the researcher assumed a uniform distribution to simplify the mathematics. Another

area of possible follow-on research would be to analyze the model using a normal distribution. Since a normal distribution is more realistic to cost estimation, the results of this research would be more precise.

4. Models For Other Contract Types

Another logical follow-on research topic would be to develop similar models for other contract types. The other incentive contracts, in particular, would be strong candidates for mathematical models. A FPIF mathematical model by itself would be relatively useless to the contracting community given how infrequent FPIF contracts are used. However, a collection of computer models, representing a wide variety of contract types, would be an asset to contracting personnel.

5. Upgrading the Computer Program

Another potential follow-on research idea addressed in this thesis would be to take the current computer program and upgrade it to commercial software. Although the current version of the software is usable, it is far from being a polished commercial product. Regardless of the power of a program, if it is not accessible to users it has no value at all. One initial goal of the researcher was to develop a mathematical model that would assist contracting personnel throughout the field. An important step in getting the model

out to the field is the development of commercial software that can be used, studied, and analyzed by field personnel. Although not directly an acquisition or contracting issue, this research might be a potential joint effort between a management and computer science study.

6. Changing Cost Probability Density Functions

In this model the researcher assumed that the contractor's probability of cost distribution was independent of the share ratio and PTA. If there are only minor changes in the share ratio and PTA, this is a valid assumption. However, given larger changes in the share ratio and PTA, the contractor's probability of cost distribution will change. A thesis for possible follow-on research might be to upgrade this model such that as the share ratios and PTAs change, the contractor's probability cost distribution also changes.

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Appendix A:

Fixed-Price-Incentive-Firm Computer Program

program FPIF;

```
{ Programmer: Terry N. Toy }
{ Naval Postgraduate School }
{ Fixed-Price-Incentive-Firm Computer Analysis Program }
{ Thesis Project: MacPascal Application }

{ This program develops potential FPIF pricing arrangements. }

{ The user should set the profit percentiles based on the industry }
{ standards for FPIF type contracts. The high profit should }
{ represent a fair profit rate the contractor should earn if he/she }
{ undertakes the maximum risk for this type of contract. Likewise, }
{ the average profit and low profit rates should represent a fair }
{ profit rate if the contractor has average or low risk given this }
{ type of contract. The user can adjust these constants below: }
```

var

count : integer;	{number of BAFOs and IGCEs}
BAFO : array [1..100] of real;	{array of BAFOs and IGCEs}
BAFO_total : real;	{sum of all BAFOs and IGCEs}
profit_ratio : real;	{profit % at target cost}
STD : real;	{Std Dev of BAFOs and IGCEs}
AVG_BAFO : real;	{Average of all BAFOs and IGCEs}
target_profit : real;	{Target profit}
cost : array [-4..6] of real;	{cost array incremented by half STD}
profit : array [-4..6] of real;	{profit array based on STD}
KTRratio : real;	{Contractor share ratio}
CV, CP, PTA : real;	{Co Variance, Ceiling Price, PTA}
Pcost : array [1..5] of real;	{Probability Costs 3,20,50,80,97%}
c1, c2, c3, c4, c5 : real;	{coefficients for options}

{various risk mgmt user input assessments to calc profit rate }

```
cost_risk, tech_risk, mgmt_risk, check_sum : real;
risk_menu_1, risk_menu_2, risk_menu_3 : integer;
tech_risk_value, mgmt_risk_value, cost_risk_value : real;
```

{miscellaneous variables}


```

STDsum : real;
temp, temp_STD1, temp_STD2, temp_STD3, temp_STD4, temp_STD5,
temp_STD6 : real;
continue, main_continue, Alarm, adequate_competition : boolean;
dummy_key : char;
choice1, choice2, continue_menu, competition_choice : integer;
i, fine_tune_menu, profit_menu_1 : integer;
temp_count, denum, main_menu_continue : integer;
select_count1, select_count2 : integer;
temp_AVG_BAFO, temp_target_profit, temp_profit_ratio : real;
underKTRratio, overKTRratio : real;
high_profit, avg_profit, low_profit : real;

```

```

{ INTRODUCTION prints out the basic user information and }
{ background to the software application. Included are the }
{ requirements and purpose of the computer program          }

```

```

procedure INTRODUCTION;
begin

```

```

    writeln;
    writeln('          * * * * FPIF Computer Aided Analysis * * * * ');
    writeln;
    writeln('This program is designed to assist contracting personnel analyze &
            develop potential pricing arrangements for FPIF type contracts. With
            this software , personnel can ask "what if "questions and quickly
            adjust FPIF arrangements . ');
    writeln;
    writeln('The computer program requires the following information:');
    writeln('          extensive cost data');
    writeln('          all profit guidelines ');
    writeln('          answers to various questions to develop pricing strategy');
    writeln;
    writeln('As with all computer applications, this program requires accurate
            information in order to develop a viable FPIF arrangement. Without
            good input information, this program cannot provide the user with any
            valuable results ');
    writeln;
    writeln('Furthermore, the more information (more BAFOs/IGCEs/profit
            data/ cost probabilities) the better the results. Any computer results

```

derived from limited information should not be the primary means of evaluating the pricing arrangement ');

writeln;

writeln('For more detailed information, consult the user manual');

writeln;

write('Press "RETURN" to continue.');

read(dummy_key);

writeln;

writeln;

end;

{ INITIALIZE sets all variables to zero. This procedure is called }
{ at the beginning of the program and when the user resets the }
{ program in one of the menu options in the main program. }

procedure INITIALIZE;

var

i : integer;

begin

for i := 1 to 100 do

begin

BAFO[i] := 0;

end;

for i := -3 to 6 do

begin

profit[i] := 0;

cost[i] := 0;

end;

for i := 1 to 5 do

Pcost[i] := 0;

count := 0;

choice1 := 0;

choice2 := 0;

BAFO_total := 0;

AVG_BAFO := 0;

STD := 0;

KTRratio := 0;

target_profit := 0;

profit_ratio := 0;

CV := 0;

```

KTRratio := 0;
STDsum := 0;
CP := 0;
PTA := 0;
select_count1 := 0;
select_count2 := 0;
temp_STD1 := 0;
temp_STD2 := 0;
temp_STD3 := 0;
temp_STD4 := 0;
temp_STD5 := 0;
temp_STD6 := 0;
end;

```

```

procedure SELECT_ADEQUATE_OR_LIMITED_COMPETITION;

```

```

begin

```

```

    continue := true;

```

```

    while continue = true do

```

```

        begin

```

```

            writeln;

```

```

            writeln('This program takes two different approaches to developing a
                    pricing structure based on the availability of or lack of adequate
                    contractor competition. ');

```

```

            writeln('If there is not adequate competition, then this program requires
                    additional cost data to determine the cost risk and variances. ');

```

```

            writeln;

```

```

            writeln('GENERAL RULE: Four or more competitive proposals is adequate
                    competition. One proposal (sole source) is limited competition. If
                    you have two or three competitive proposals, you may want to do
                    both a limited & adequate competition analysis. ');

```

```

            writeln;

```

```

            writeln(' Please enter the correct number from the below menu:  ');

```

```

            writeln;

```

```

            writeln('1: Adequate Competition');

```

```

            write('2: Limited Competition.  ');

```

```

            readln(Competition_choice);

```

```

    if competition_choice = 1 then

```

```

        Adequate_Competition := true

```

```

    else

```

```

        Adequate_Competition := false;

```

```

if (competition_choice > 0) and (competition_choice < 3) then
    continue := false
else
    begin
        writeln;
        writeln('***Your selection did not make sense, please try again.***');
        writeln;
        continue := true;
    end;
end;
end;

```

```

{ GET_BAFOS prompts the user to input all BAFO and IGCE cost data }
{ Data is entered and stored in an array of real numbers.  Maximun   }
{ number of BAFOs and/or IGCEs is 100 (the size of the array)       }

```

```

procedure GET_BAFOS;
begin
    writeln;
    writeln('This computer application requires the user to rank all the
        BAFOs/IGCEs in order from most to least reliable cost proposals. In
        other words, the first BAFO/IGCE entered should be the users opinion
        of the company ');
    writeln('with the most realistic cost proposal based on that companys
        historical "reliability" records, capital and labor assets, concurrent
        contract work, and any other important factor deemed by the user to
        affect reliability. ');
    writeln('Likewise, the last BAFO / IGCE entered should be the least reliable
        cost proposal as evaluated by the user. ');
    writeln;
    writeln('Remember, the better and more complete the input data, the better
        the output data. Any offers from companies that the user determines
        to be outside the competitive range, should be considered invalid data
        and not entered into the computer. ');
    writeln;
    writeln('Enter BAFOs/IGCEs now. After each entry press "return". ');
    writeln('When finished, type "-1" to exit');
    writeln;
    write(' ');
    readln(temp);

```

```

while temp <> -1 do
  begin
    count := count + 1;
    BAFO[count] := temp;
    write('    ');
    readln(temp);
  end;
end;

procedure GET_COST_DATA;
  var
    i : integer;
begin
  writeln;
  writeln('With limited competition, it is difficult to gain a good perspective
    of potential cost variances. This program requires the user to input
    the 3%, 20%, 50%, 80%, and 97% estimated cost probabilities. ');
  writeln;
  writeln('This information should be gathered from the contractors proposal,
    fact-finding , negotiations , and other sources . ');
  writeln;
  writeln('DEFINITION: The XX% probability cost is the estimated cost for
    which there is a XX% probability that the contractor will be able to
    complete the contract for this cost or less . ');
  writeln;
  writeln('Another way to look at this data is as follows: The 3% probability
    cost is the cost that the contractor will incur if almost EVERYTHING
    goes perfectly. ');
  writeln('Likewise, the 50% probability cost is the approximate cost that
    the contractor will bear assuming everything goes as expected. The
    97% prob cost is the cost that the contractor will incur if virtually
    EVERYTHING that can go wrong, does go wrong ');
  writeln;
  writeln('NOTE: costs should increase as the probabilities increase. In other
    words, the 97% probability cost should be the largest, and the 3%
    probability should be the lowest. ');
  writeln;
  continue := true;
  while continue = true do
    begin
      write('Enter 3 % Probability Costs: ');

```



```

readln(Pcost[1]);
write('Enter 20 % Probability Costs: ');
readln(Pcost[2]);
write('Enter 50 % Probability Costs: ');
readln(Pcost[3]);
write('Enter 80 % Probability Costs: ');
readln(Pcost[4]);
write('Enter 97 % Probability Costs: ');
readln(Pcost[5]);
writeln;

if (Pcost[1] < Pcost[2]) and (Pcost[2] < Pcost[3]) and (Pcost[3] < Pcost[4])
    and (Pcost[4] < Pcost[5]) then
    continue := false
else
    begin
        writeln;
        writeln('*** You have made an error ***');
        writeln('Please try again. Your costs must increase as the
            probabilities increase . ');
        writeln;
        continue := true;
    end;
end;
end;

```

```

{ GET_PROFIT allows the user to input a profit rate directly or }
{ presents the user with a battery of risk assessment question }
{ to calculate a profit rate with the computer. This rate can be }
{ fined tuned later in the main program to user's desires.      }
{ This profit rate will be used to calc profit at Target Cost.   }

```

```

procedure GET_PROFIT;
begin
    writeln;
    writeln('An effective FPIF pricing structure requires a fair and reasonable
        profit rate. This program allows the user to directly input a target
        profit rate. This rate should be based on Weighted Guidelines or
        historical stds. ');
    writeln('If the user does not have a WGL profit calculation or reliable
        historical data, this program will calculate a profit rate based on the

```



```

    the users assessment of the contract risk conditions . ');
writeln;
writeln('Please select from the following menu:');
writeln;
writeln('1:  User will enter profit rate into the computer directly. ');
write('2:  User would like the  software application to develop initial profit
        percentage based on the users answers to specific risk assessment
        questions.  The user will be able to fine tune the computer profit rate
        later.  ');
readln(profit_menu_1);
writeln;

if profit_menu_1 = 1 then
    begin
        continue := true;
        while continue = true do
            begin
                write('Please enter the target profit rate.  Be sure you enter the rate
                        as a decimal.  For example 10% profit should be entered as 0.10  ');
                readln(profit_ratio);
                if profit_ratio <= 1 then
                    continue := false
                else
                    writeln('Your select did not make sense. Please re-enter your profit
                            rate as a decimal less than 1.00. ');
            end;
        end
    end

else
    begin
        writeln('To calculate a fair and reasonable profit rate, the computer
                model needs to know the industry standards for profit. ');
        writeln;
        writeln('You will be required to enter three profit rates based on
                industry standards.  These rates are: (1) maximum profit rate (2)
                average profit rate (3) low profit rate.  The high profit rate is
                that rate within the industry');
        writeln('that a contractor would expect to earn given a high risk
                performance contract with a strict schedule.  The average profit
                rate is that rate usually earned for a standard or average workload.

```

```

        And the low profit rate');
writeln('is that rate a contractor would earn given a very low risk
        contract . ');
writeln;
write('In decimal form, input the maximum profit rate ');
readln(high_profit);
write('In decimal form, input the average profit rate ');
readln(avg_profit);
write('In decimal form, input the low profit rate ');
readln(low_profit);
writeln;
writeln('This program computes a profit percentage based on the users
        assessment of the required risk management . The software takes
        into consideration three types of risk : Technical , Management and
        Cost Control . ');
writeln;
writeln('Input your evaluation of the areas of risk by assigning a
        percentage for each of the three risk types. Your total percentage
        should equal 1.00. The greater the percentage, the greater the risk
        in that particular area ');
writeln;
writeln('For example, a contract that uses advance technology will have
        a relatively high technical weight. A contract that requires
        extensive coordination or a strict delivery schedule will have a
        relatively high mgmt weight');
writeln('Similarly, a contract that requires high initial start-up capital
        or requires a substantial quantity of materials with volatile prices
        should have a relatively high cost risk weighting. ');
writeln;
writeln('Enter your risk assessments in the following format.
        Remember, the three weightings should total 1.00 . ');
writeln;
writeln('Technical Risk: 0.30 ', ' Technical Risk: 0.50');
writeln('Management Risk: 0.50', ' Management Risk: 0.25');
writeln('Cost Control Risk: 0.20', ' Cost Control Risk : 0.25 ');
writeln;

continue := true;
while continue = true do
begin
    writeln;

```

```

writeln('Input your weightings now');
writeln;
write('Technical Risk: ');
readln(tech_risk);
write('Mangement Risk: ');
readln(mgmt_risk);
write('Cost Control Risk: ');
readln(cost_risk);
writeln;
writeln;
check_sum := tech_risk + mgmt_risk + cost_risk;
if check_sum = 1 then
    continue := false
else
    writeln('Your assigned risk inputs did not total 1.00. Please input
           these risk weighting again.');
```

end;

```

continue := true;
while continue = true do
    begin
        writeln;
        writeln('Input your assessment of the Technical Risk based on the
                below menu.');
```

writeln;

```

        writeln('Some factors that should influence your technical risk
                assessment include: use of state of the art technology, relative
                degree of percision and tolerances, complexity of product or
                service, level and experience of engineering staff. ');
        writeln;
        writeln(' 1: high technical risk ');
        writeln(' 2: above average technical risk ');
        writeln(' 3: average technical risk ');
        writeln(' 4: below average technical risk ');
        write(' 5: low technical risk ');
        readln(risk_menu_1);
        if (risk_menu_1 > 0) and (risk_menu_1 < 6) then
            continue := false
        else
            writeln('***Your selection did not make sense. Please try
                    again.***');
```

```
writeln;  
end;
```

```
continue := true;
```

```
while continue = true do
```

```
begin
```

```
  writeln('Input your assessment of the Management Risk based on the  
    below menu.');
```

```
  writeln;
```

```
  writeln('Some factors that should influence your management risk  
    assessment include: relative degree of inter-division or  
    subcontracting coordination, strict schedule requirements , level  
    and experience of management support and oversight. ');
```

```
  writeln;
```

```
  writeln(' 1: high management risk ');
```

```
  writeln(' 2: above average mangement risk ');
```

```
  writeln(' 3: average management risk ');
```

```
  writeln(' 4: below average management risk ');
```

```
  write(' 5: low management risk ');
```

```
  readln(risk_menu_2);
```

```
  if (risk_menu_2 > 0) and (risk_menu_2 < 6) then
```

```
    continue := false
```

```
  else
```

```
    writeln('***Your selection did not make sense. Please try  
      again.***');
```

```
  writeln;
```

```
end;
```

```
continue := true;
```

```
while continue = true do
```

```
begin
```

```
  writeln;
```

```
  writeln('Input your assessment of the Cost Control Risk based on the  
    below menu.');
```

```
  writeln;
```

```
  writeln('Some factors that should influence your cost risk assessment  
    include: volitility in price of materials, amount of required start  
    up capital as percentage of total contract , government financing  
    through progress payments, length of contract. ');
```

```
  writeln;
```

```
  writeln(' 1: high cost control risk ');
```

```

writeln(' 2:  above average cost control risk ');
writeln(' 3:  average cost control risk ');
writeln(' 4:  below average cost control risk ');
write(' 5:  low cost control risk      ');
readln(risk_menu_3);
if (risk_menu_3 > 0) and (risk_menu_3 < 6) then
  continue := false
else
  writeln('***Your selection did not make sense.  Please try
        again.***');
  writeln;
end;

```

```

{ These risk weightings can be adjusted to different values }
{ The user can adjust these profit rates in the "Constant"   }

```

```

case risk_menu_1 of
  1 :
    tech_risk_value := high_profit;
  2 :
    tech_risk_value := (high_profit + avg_profit) / 2;
  3 :
    tech_risk_value := avg_profit;
  4 :
    tech_risk_value := (low_profit + avg_profit) / 2;
  5 :
    tech_risk_value := low_profit;
end;
case risk_menu_2 of
  1 :
    mgmt_risk_value := high_profit;
  2 :
    mgmt_risk_value := (high_profit + avg_profit) / 2;
  3 :
    mgmt_risk_value := avg_profit;
  4 :
    mgmt_risk_value := (low_profit + avg_profit) / 2;
  5 :
    mgmt_risk_value := low_profit;
end;

```


case risk_menu_3 **of**

1 :

cost_risk_value := high_profit;

2 :

cost_risk_value := (high_profit + avg_profit) / 2;

3 :

cost_risk_value := avg_profit;

4 :

cost_risk_value := (low_profit + avg_profit) / 2;

5 :

cost_risk_value := low_profit;

end;

profit_ratio := ((tech_risk_value * tech_risk) + (mgmt_risk_value *
mgmt_risk) + (cost_risk_value * cost_risk))

end;

end;

{ BASIC CALC computes the Standard Deviation, average weighted }
{ BAFO/IGCEs, target profit (profit at Target Cost), and Co Variance.}
{ The average weighted BAFO assigns a heavier weighting to the higher }
{ prioritized (those deemed more reliable) cost proposals. }

procedure BASIC_CALC;

var

i : integer;

begin

BAFO_total := 0;

denum := 0;

temp_count := count;

for i := 1 **to** count **do**

begin

BAFO_total := BAFO[i] * temp_count + BAFO_total;

denum := denum + temp_count;

temp_count := temp_count - 1;

end;

AVG_BAFO := BAFO_total / denum;

for i := 1 **to** count **do**

begin


```

    BAFO_total := BAFO[i] + BAFO_total;

end;

STDsum := 0;

for i := 1 to count do
    begin
        STDsum := STDsum + (AVG_BAFO - BAFO[i]) * (AVG_BAFO - BAFO[i]);
    end;
STDsum := STDsum / count;
STD := sqrt(STDsum);
target_profit := AVG_BAFO * profit_ratio;
CV := STD / AVG_BAFO;
end;

procedure BASIC_CALC_FOR_LIMITED_COMP;

var
    i : integer;

begin
    AVG_BAFO := Pcost[3];
    temp_STD1 := (Pcost[5] - Pcost[3]) / 2;
    temp_STD2 := Pcost[4] - Pcost[3];
    temp_STD3 := Pcost[3] - Pcost[2];
    temp_STD4 := (Pcost[3] - Pcost[1]) / 2;
    temp_STD5 := Pcost[2] - Pcost[1];
    temp_STD6 := Pcost[5] - Pcost[4];
    STD := (temp_STD1 + temp_STD2 + temp_STD3 + temp_STD4 + temp_STD5 +
        temp_STD6) / 6;
    target_profit := AVG_BAFO * profit_ratio;
end;

{ CALC_PROFIT_STRUCTURE assigns a profit value for each element }
{ in the profit array. Target profit is the first value assigned to the }
{ target cost. Thereafter, profit is increased or decreased as cost }
{ moves farther from Target Cost according to the contractor share }
{ ratio. This procedure is called in the main program and in the next }
{ procedure CALC_INCENTIVE_STRUCTURE .}

```

```
procedure CALC_PROFIT_STRUCTURE;  
begin
```

```
  c1 := 0.239583 * STD;  
  c2 := 0.2 * STD;  
  c3 := 0.35625 * STD;  
  c4 := 0.066666 * STD;  
  c5 := 0.0645833 * STD;
```

```
if choice1 = 1 then
```

```
  begin
```

```
    profit[-4] := target_profit + c1 + KTRratio * 2 * STD;  
    profit[-3] := target_profit + c1 + KTRratio * 1.5 * STD;  
    profit[-2] := target_profit + c1 + KTRratio * 1 * STD;  
    profit[-1] := target_profit + c1 + KTRratio * 0.5 * STD;  
    profit[0] := target_profit + c1;  
    profit[1] := target_profit + c1 - KTRratio * 0.5 * STD;  
    profit[2] := profit[1] - 0.5 * STD;  
    profit[3] := profit[2] - 0.5 * STD;  
    profit[4] := profit[3] - 0.5 * STD;  
    profit[5] := profit[4] - 0.5 * STD;  
    profit[6] := profit[5] - 0.5 * STD;  
    PTA := cost[1];  
    CP := PTA + profit[1];  
  end;
```

```
if choice1 = 2 then
```

```
  begin
```

```
    profit[-4] := target_profit + c2 + KTRratio * 2 * STD;  
    profit[-3] := target_profit + c2 + KTRratio * 1.5 * STD;  
    profit[-2] := target_profit + c2 + KTRratio * 1 * STD;  
    profit[-1] := target_profit + c2 + KTRratio * 0.5 * STD;  
    profit[0] := target_profit + c2;  
    profit[1] := target_profit + c2 - KTRratio * 0.5 * STD;  
    profit[2] := target_profit + c2 - KTRratio * 1 * STD;  
    profit[3] := profit[2] - 0.5 * STD;  
    profit[4] := profit[3] - 0.5 * STD;  
    profit[5] := profit[4] - 0.5 * STD;  
    profit[6] := profit[5] - 0.5 * STD;  
    PTA := cost[2];
```

```

    CP := PTA + profit[2];
end;

if choice1 = 3 then
begin
    profit[-4] := target_profit + c3 + KTRratio * 2 * STD;
    profit[-3] := target_profit + c3 + KTRratio * 1.5 * STD;
    profit[-2] := target_profit + c3 + KTRratio * 1 * STD;
    profit[-1] := target_profit + c3 + KTRratio * 0.5 * STD;
    profit[0] := target_profit + c3;
    profit[1] := target_profit + c3 - KTRratio * 0.5 * STD;
    profit[2] := target_profit + c3 - KTRratio * 1 * STD;
    profit[3] := target_profit + c3 - KTRratio * 1.5 * STD;
    profit[4] := profit[3] - 0.5 * STD;
    profit[5] := profit[4] - 0.5 * STD;
    profit[6] := profit[5] - 0.5 * STD;
    PTA := cost[3];
    CP := PTA + profit[3];
end;

if choice1 = 4 then
begin
    profit[-4] := target_profit + c4 + KTRratio * 2 * STD;
    profit[-3] := target_profit + c4 + KTRratio * 1.5 * STD;
    profit[-2] := target_profit + c4 + KTRratio * 1 * STD;
    profit[-1] := target_profit + c4 + KTRratio * 0.5 * STD;
    profit[0] := target_profit + c4;
    profit[1] := target_profit + c4 - KTRratio * 0.5 * STD;
    profit[2] := target_profit + c4 - KTRratio * 1 * STD;
    profit[3] := target_profit + c4 - KTRratio * 1.5 * STD;
    profit[4] := target_profit + c4 - KTRratio * 2 * STD;
    profit[5] := profit[4] - 0.5 * STD;
    profit[6] := profit[5] - 0.5 * STD;
    PTA := cost[4];
    CP := PTA + profit[4];
end;

if choice1 = 5 then
begin
    profit[-4] := target_profit + c5 + KTRratio * 2 * STD;
    profit[-3] := target_profit + c5 + KTRratio * 1.5 * STD;

```

```

profit[-2] := target_profit + c5 + KTRratio * 1 * STD;
profit[-1] := target_profit + c5 + KTRratio * 0.5 * STD;
profit[0] := target_profit + c5;
profit[1] := target_profit + c5 - KTRratio * 0.5 * STD;
profit[2] := target_profit + c5 - KTRratio * 1 * STD;
profit[3] := target_profit + c5 - KTRratio * 1.5 * STD;
profit[4] := target_profit + c5 - KTRratio * 2 * STD;
profit[5] := target_profit + c5 - KTRratio * 2.5 * STD;
profit[6] := profit[5] - 0.5 * STD;
PTA := cost[5];
CP := PTA + profit[5];
end;

```

if choice1 = 6 then

begin

```

profit[-4] := target_profit + underKTRratio * 2 * STD;
profit[-3] := target_profit + underKTRratio * 1.5 * STD;
profit[-2] := target_profit + underKTRratio * 1 * STD;
profit[-1] := target_profit + underKTRratio * 0.5 * STD;
profit[0] := target_profit;
profit[1] := target_profit - overKTRratio * 0.5 * STD;
profit[2] := target_profit - overKTRratio * 1 * STD;
profit[3] := target_profit - overKTRratio * 1.5 * STD;
profit[4] := target_profit - overKTRratio * 2 * STD;
profit[5] := profit[4] - 0.5 * STD;
profit[6] := profit[5] - 0.5 * STD;
PTA := cost[4];
CP := PTA + profit[4];
end;

```

if choice1 = 7 then

begin

```

profit[-4] := target_profit + underKTRratio * 2 * STD;
profit[-3] := target_profit + underKTRratio * 1.5 * STD;
profit[-2] := target_profit + underKTRratio * 1 * STD;
profit[-1] := target_profit + underKTRratio * 0.5 * STD;
profit[0] := target_profit;
profit[1] := target_profit - overKTRratio * 0.5 * STD;
profit[2] := target_profit - overKTRratio * 1 * STD;
profit[3] := profit[2] - 0.5 * STD;
profit[4] := profit[3] - 0.5 * STD;

```

```

writeln(' 2 : pricing arrangement should give strong profit incentive for
        contractor to under run cost in exchange for moderate penalties for
        an over run ');
writeln(' 3 : pricing arrangement should give average profit incentive for
        contractor to under run cost in exchange for some protection
        against an over run ');
writeln(' 4 : pricing arrangement should give a small profit incentive for
        contractor to under run cost in exchange for substantial protection
        against an over run ');
writeln(' 5 : pricing arrangement should give minimal profit incentive for
        contractor to under run cost in exchange for maximum protection
        against an over run ');
writeln('   SPECIAL Pricing Arrangements   ');
writeln(' 6 : pricing arrangement will have different share ratios above &
        below target cost. The arrangement will give both a strong profit
        incentive to under run costs and a strong protection against an over
        run.           ');
write(' 7 : pricing arrangement will have different share ratios above &
        below target cost. The arrangement will give modest profit
        incentive to under run costs and limited protection against an over
        run.           ');
readln(choice1);
writeln;
if (choice1 > 0) and (choice1 < 8) then
    continue := false
else
    writeln('***Your selection did not make sense. Please try again.***');
    writeln;
end;

```

```

Alarm := False;
if (choice1 = 6) or (choice1 = 7) then
    Alarm := True;

```

```

KTRratio := 0;
underKTRratio := 0;
overKTRratio := 0;

```

```

if choice1 = 1 then
    KTRratio := 0.5;
if choice1 = 2 then

```

```

KTRratio := 0.4;
if choice1 = 3 then
  KTRratio := 0.3;
if choice1 = 4 then
  KTRratio := 0.2;
if choice1 = 5 then
  KTRratio := 0.1;
if choice1 = 6 then
  begin
    underKTRratio := 0.4;
    overKTRratio := 0.2;
  end;
if choice1 = 7 then
  begin
    underKTRratio := 0.2;
    overKTRratio := 0.4;
  end;

```

CALC_PROFIT_STRUCTURE;

end;

{ PRINT_DATA displays all of the results }

procedure PRINT_DATA_Special;

begin

writeln;

writeln(' Target Cost is ', temp_AVG_BAFO : 10 : 3);

writeln(' Target Profit % is ', temp_profit_ratio : 10 : 3);

writeln(' Target Profit is ', temp_target_profit : 10 : 3);

writeln(' Contractor Share Ratio is ', KTRratio : 10 : 3);

writeln;

end;

procedure PRINT_DATA1;

begin

writeln;

writeln(' Target Cost is ', AVG_BAFO : 10 : 3);

writeln(' Target Profit is ', profit[0] : 10 : 3);

if KTRratio <> 0 **then**

writeln(' Contractor Share Ratio is ', KTRratio : 10 : 3)


```

else
    writeln('    Contractor Share Ratio above/below target cost is ',
        overKTRratio : 10 : 3, underKTRratio : 10 : 3);

    writeln;
end;

procedure PRINT_DATA2;

var
    i : integer;

begin

    for i := -4 to 6 do
        begin
            writeln('    cost    ', cost[i] : 10 : 3, '    profit    ', profit[i] : 10 : 3);
        end;
    writeln;
    writeln('    Point of Total Assumption is    ', PTA : 10 : 3);
    writeln('    Ceiling Price is    ', CP : 10 : 3);
    writeln;
end;

begin {main}

INTRODUCTION;
main_continue := true;
while main_continue = true do
begin
    INITIALIZE;
    SELECT_ADEQUATE_OR_LIMITED_COMPETITION;

    if ADEQUATE_COMPETITION then
        begin
            GET_BAFOS;
            GET_PROFIT;
            BASIC_CALC;
            CALC_INCENTIVE_STRUCTURE;
            PRINT_DATA1;

```

```
PRINT_DATA2;
```

```
continue := true;
```

```
while continue = true do
```

```
  begin
```

```
    writeln('      **** Select from the below menu to continue **** ');
```

```
    writeln;
```

```
    writeln(' 1: reset program and begin with new BAFOs & IGCEs');
```

```
    writeln(' 2: revise profit analysis ');
```

```
    writeln(' 3: revise incentive structure analysis');
```

```
    writeln(' 4: fine tune the existing pricing structure');
```

```
    write(' 5: exit to main menu      ');
```

```
    readln(continue_menu);
```

```
if continue_menu = 1 then
```

```
  begin
```

```
    INITIALIZE;
```

```
    GET_BAFOS;
```

```
    GET_PROFIT;
```

```
    BASIC_CALC;
```

```
    CALC_INCENTIVE_STRUCTURE;
```

```
    PRINT_DATA1;
```

```
    PRINT_DATA2;
```

```
  end;
```

```
if continue_menu = 2 then
```

```
  begin
```

```
    GET_PROFIT;
```

```
    BASIC_CALC;
```

```
    CALC_INCENTIVE_STRUCTURE;
```

```
    PRINT_DATA1;
```

```
    PRINT_DATA2;
```

```
  end;
```

```
if continue_menu = 3 then
```

```
  begin
```

```
    CALC_INCENTIVE_STRUCTURE;
```

```
    PRINT_DATA1;
```

```
    PRINT_DATA2;
```

```
  end;
```

```

if continue_menu = 4 then
  begin

    writeln;
    writeln;
    writeln('You have selected option 4, which allows the user to fine
      tune the existing pricing structure. This option will make
      minor adjustments in the pricing arrangement. Select the
      appropriate number based on the below menu.');
```

writeln;

```

    writeln(' NOTE: If you have selected a SPECIAL Pricing
      Arrangement, you will not be able to select fine tune options
      3-6');
```

writeln;

```

    writeln(' 1 : profit is too high;  reduce profit. ');
    writeln(' 2:  profit is too low;  increase profit. ');
    writeln(' 3:  contractor share ratio is too high;  reduce share
      ratio.');
```

writeln(' 4: contractor share ratio is too low; increase share
 ratio. ');

```

    writeln(' 5:  keep same pricing structure, but lower the target cost
      ');
    write(' 6:  keep same pricing structure, but raise the target cost
      ');
    readln(fine_tune_menu);

if fine_tune_menu = 1 then
  begin
    profit_ratio := profit_ratio - 0.005;
    BASIC_CALC;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
  end;

if fine_tune_menu = 2 then
  begin
    profit_ratio := profit_ratio + 0.005;
    BASIC_CALC;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
```

```

    PRINT_DATA2;
end;
if (fine_tune_menu = 3) and (Alarm = false) then
begin
    KTRratio := KTRratio - 0.05;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
end;
if (fine_tune_menu = 4) and (Alarm = false) then
begin
    KTRratio := KTRratio + 0.05;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
end;
if (fine_tune_menu = 5) and (Alarm = false) then
begin
    select_count1 := select_count1 + 1;
    temp_AVG_BAFO := AVG_BAFO - 0.5 * STD * (select_count1 -
        select_count2);
    temp_target_profit := target_profit + 0.5 * STD * KTRratio *
        (select_count1 - select_count2);
    temp_profit_ratio := temp_target_profit / temp_AVG_BAFO;
    PRINT_DATA_Special;
    PRINT_DATA2;
end;
if (fine_tune_menu = 6) and (Alarm = false) then
begin
    select_count2 := select_count2 + 1;
    temp_AVG_BAFO := AVG_BAFO + 0.5 * STD * (select_count2 -
        select_count1);
    temp_target_profit := target_profit - 0.5 * STD * KTRratio *
        (select_count2 - select_count1);
    temp_profit_ratio := temp_target_profit / temp_AVG_BAFO;
    PRINT_DATA_SPECIAL;
    PRINT_DATA2;
end;
if (fine_tune_menu > 2) and (fine_tune_menu < 7) and (Alarm =

```

```

        true) then
begin
    writeln;
    writeln(' You have selected a SPECIAL Pricing Arrangement.
            This application cannot process your request. ');
    writeln;
end;

if (fine_tune_menu < 1) or (fine_tune_menu > 6) then
begin
    writeln;
    writeln('***Your selection did not make sense. Please try
            again.***');
    writeln;
end;
end;

continue := true;
if continue_menu = 5 then
begin
    continue := false;
end;

if (continue_menu < 1) or (continue_menu > 5) then
begin
    writeln;
    writeln('***Your selection did not make sense. Please try
            again.***');
    writeln;
end;

end;

writeln;

end;

if not ADEQUATE_COMPETITION then
begin
    GET_COST_DATA;

```

```
GET_PROFIT;  
BASIC_CALC_FOR_LIMITED_COMP;  
CALC_INCENTIVE_STRUCTURE;  
PRINT_DATA1;  
PRINT_DATA2;
```

```
continue := true;
```

```
while continue = true do
```

```
  begin
```

```
    writeln('      **** Select from the below menu to continue **** ');  
    writeln;  
    writeln(' 1:  reset program and begin with new cost probabilities');  
    writeln(' 2:  revise profit analysis ');  
    writeln(' 3:  revise incentive structure analysis');  
    writeln(' 4:  fine tune the existing pricing structure');  
    write(' 5:  exit to main menu      ');  
    readln(continue_menu);
```

```
if continue_menu = 1 then
```

```
  begin
```

```
    INITIALIZE;  
    GET_COST_DATA;  
    GET_PROFIT;  
    BASIC_CALC_FOR_LIMITED_COMP;  
    CALC_INCENTIVE_STRUCTURE;  
    PRINT_DATA1;  
    PRINT_DATA2;
```

```
  end;
```

```
if continue_menu = 2 then
```

```
  begin
```

```
    GET_PROFIT;  
    BASIC_CALC_FOR_LIMITED_COMP;  
    CALC_INCENTIVE_STRUCTURE;  
    PRINT_DATA1;  
    PRINT_DATA2;
```

```
  end;
```

```
if continue_menu = 3 then
```

```
  begin
```



```
    CALC_INCENTIVE_STRUCTURE;  
    PRINT_DATA1;  
    PRINT_DATA2;  
end;
```

```
if continue_menu = 4 then  
begin
```

```
    writeln;  
    writeln;  
    writeln('You have selected option 4, which allows the user to fine  
        tune the existing pricing structure. This option will make  
        minor adjustments in the pricing arrangement. Select the  
        appropriate number based on the below menu.');
```

```
    writeln;  
    writeln(' NOTE: If you have selected a SPECIAL Pricing  
        Arrangement, you will not be able to select fine tune options  
        3-6');
```

```
    writeln;  
    writeln(' 1 : profit is too high;  reduce profit. ');  
    writeln(' 2:  profit is too low;  increase profit. ');  
    writeln(' 3:  contractor share ratio is too high;  reduce share  
        ratio.');
```

```
    writeln(' 4:  contractor share ratio is too low;  increase share  
        ratio.  ');  
    writeln(' 5:  keep same pricing structure, but lower the target cost  
        ');  
    write(' 6:  keep same pricing structure, but raise the target cost  
        ');  
    readln(fine_tune_menu);
```

```
if fine_tune_menu = 1 then  
begin
```

```
    profit_ratio := profit_ratio - 0.005;  
    BASIC_CALC_FOR_LIMITED_COMP;  
    CALC_PROFIT_STRUCTURE;  
    PRINT_DATA1;  
    PRINT_DATA2;
```

```
end;
```

```
if fine_tune_menu = 2 then  
begin
```

```

    profit_ratio := profit_ratio + 0.005;
    BASIC_CALC_FOR_LIMITED_COMP;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
end;
if (fine_tune_menu = 3) and (Alarm = false) then
begin
    KTRratio := KTRratio - 0.05;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
end;
if (fine_tune_menu = 4) and (Alarm = false) then
begin
    KTRratio := KTRratio + 0.05;
    CALC_PROFIT_STRUCTURE;
    PRINT_DATA1;
    PRINT_DATA2;
end;
if (fine_tune_menu = 5) and (Alarm = false) then
begin
    select_count1 := select_count1 + 1;
    temp_AVG_BAFO := AVG_BAFO - 0.5 * STD * (select_count1 -
        select_count2);
    temp_target_profit := target_profit + 0.5 * STD * KTRratio *
        (select_count1 - select_count2);
    temp_profit_ratio := temp_target_profit / temp_AVG_BAFO;
    PRINT_DATA_Special;
    PRINT_DATA2;
end;

if (fine_tune_menu = 6) and (Alarm = false) then
begin
    select_count2 := select_count2 + 1;
    temp_AVG_BAFO := AVG_BAFO + 0.5 * STD * (select_count2 -
        select_count1);
    temp_target_profit := target_profit - 0.5 * STD * KTRratio *
        (select_count2 - select_count1);
    temp_profit_ratio := temp_target_profit / temp_AVG_BAFO;
    PRINT_DATA_SPECIAL;

```

```

    PRINT_DATA2;
end;

if (fine_tune_menu > 2) and (fine_tune_menu < 7) and (Alarm =
    true) then
begin
    writeln;
    writeln(' You have selected a SPECIAL Pricing Arrangement.
        This application cannot process your request. ');
    writeln;
end;

if (fine_tune_menu < 1) or (fine_tune_menu > 6) then
begin
    writeln;
    writeln('***Your selection did not make sense. Please try
        again.***');
    writeln;
end;
end;

continue := true;
if continue_menu = 5 then
begin
    continue := false;
end;

if (continue_menu < 1) or (continue_menu > 5) then
begin
    writeln;
    writeln('***Your selection did not make sense. Please try
        again.***');
    writeln;
end;
end;

end;
writeln;
writeln('Please select a number from the following menu:');

```

```
writeln('1:  exit program');
write('2:  reset program, return to main menu.  ');
read(main_menu_continue);
writeln;
if main_menu_continue = 1 then
  main_continue := false
else
  main_continue := true;
end;
writeln;
writeln;
writeln(' ****  Thank You for Using this Program  **** ');
end.
```

Appendix B:

Electronic Testing Corporation Case Study

NOTE: The answers typed in for this case represent the composite answers of all of the student groups.

Electrical Testing Incorporated Case
Fixed-Price-Incentive-Firm Contract Type

You are a senior contracting officer employed by Electrical Testing Corporation (ETC) a high tech company with over 50 service facilities throughout the world. ETC is a company that provides advance electronic testing to computer and electronic manufacturers throughout the world. Since the early 1980s, when high technology manufacturers learned that finding a defect in electronic components before assembly is significantly less expensive than finding the defect after assembly, the electronic testing service market has grown by almost 1000%.

As one of the more experienced contracting officers, you have been assigned to work on the XYZ acquisition project--an advance machine that will greatly enhance the productivity at ETC. Your company's technical staff has described the machine as "an advance technological accomplishment that will require high level engineering support to ensure its proper construction." The XYZ will be a modern electronic apparatus capable of testing a wide variety of advance electronic and computer chips. ETC is planning to purchase five XYZ machines. If the machine proves as successful as predicted, ETC will expand production and purchase ten more machines each year for the next five years. These machines will replace current testing machines at ETC testing centers throughout the world.

Your supervisor has recently informed you that your major competition is also planning a similar expansion into this high tech market. Since your company is committed to being the first to offer this service, your contract specifications for the initial five XYZ machines require a strict delivery schedule (12 months). Normally, a project of this magnitude would require at least 14 months. However, a 12 month delivery schedule is not unrealistic or unreasonable if given adequate contractor management attention.

You recently issued a Request for Quotation to seven companies (Company A - Company G) that you think may be qualified to build the XYZ machine. All seven companies replied. Your acquisition team met with each of these companies. They are satisfied that each of these companies can build the XYZ machine in accordance with the specifications except for Company G. Your team has determined that Company G, given the 12 month delivery schedule, cannot build the XYZ machine on time, because of its current lack of key materials, personnel, and experience. In addition, you have also assigned some of your cost analysts to prepare an independent cost estimate. The bottom

line of the cost analyst report and the contractors' proposals are shown in Exhibit 1 with your "reliability" assessment of each document.

One of your primary concerns is developing an incentive for the contractor to control costs. Based on the risk and your acquisition strategy, you are planning to use a FPIF type contract. One aspect of developing an effective incentive pricing structure is determining a fair and reasonable profit rate. To determine a fair rate, you researched company files and all published data for similar purchases with FPIF contracts. You found four similar cases that were awarded within the last three years. The target profit rates (profit rate at target cost) in these purchases ranged between 9-10.5%. However, these cases did not require an accelerated delivery schedule. You have also noted that in three out of four of these cases, the actual costs ran slightly over the target costs. In the fourth case, the actual costs were substantially lower than target costs, and the contractor earned a healthy profit. Although this information is valuable as a guide, you realize that this data cannot be compared directly to your acquisition, given the variety of negotiation positions and/or strategies in any one contract.

From your experience, you have noticed that high tech companies tend to perform well on contracts in which there is an incentive for high financial reward. Based on this observation, you have recommended that ETC use an FPIF arrangement that will offer a high profit to the contractor if he/she under runs. However, you are also aware of your company's current budget restraints. Due to the prolonged 1991-1992 recession, the silicon chip business has been temporarily stalled. Your company's top management has adopted a strict policy to review all large expenditures and evaluate the decision and rationale for the expense. You are concerned that if the contractor for the XYZ machine earns an unjustified high profit, your contract will get an unfavorable review by top management, and your reputation in the company will be tarnished.

Your supervisor, the Director of Contracts, recently met with you and said, "Implement your plan as you see fit." He has great confidence in you and your abilities. His only recommendation was to award the contract as soon as possible. "We need to have this machine up and running before our competitors get it."

Cost Proposals and Estimate For the XYZ Machine
(EXHIBIT 1)

	<u>Proposal</u>	<u>* Reliability Assessment</u>
Company A:	2,212,000	Very High
Company B:	2,190,000	High
Company C:	2,005,000	High
Company D:	2,310,000	High
Company E:	2,130,000	Good
Company F:	2,090,000	Good
Company G:	1,925,000	Poor
ETC Cost Est:	2,195,000	Good

(Figures represent cost of building the XYZ machines IAW the specifications. These figures are cost only, and do not include profit.)

* Reliability Assessment is a ranking the cost analyst put on each proposal based on the proposal's accuracy, information in the proposal, the contractor's performance record, and current market conditions. Possible assessment categories are very high, high, good, fair, and poor.

Questions:

1. On the graph paper provided, develop an initial, generic FPIF pricing arrangement for this case. Include your Ceiling Price, contractor share ratio, PTA, Target Cost, and Target Profit. (These can be estimates from your graph.)
2. How did you determine your target costs?
 - a. Averaged more reliable proposals-- then rounded
 - b. Used independent estimate as check and balance
3. How did you determine your target profit?
 - a. Used historical records of past profit rates
 - b. Adjusted for higher risk in this contract
4. How did you determine your point of total assumption?
 - a. Used mathematical formula based on ceiling price, share ratio, and target price
5. How did you determine your Ceiling Price?
 - a. Based on a percentage of target cost
6. How did you determine your share ratio?
 - a. Based on personal strategy
 - b. share ratios varied among all groups

7. What factors led you to your strategy? What thought process did you follow? If possible, list (or flowchart) the steps you followed in your thought process to develop your plan.

a. Use competition to determine target cost. Be reasonable.

b. Analyse risk and historical records.

c. Evaluate the overall arrangement. Ensure arrangement is reasonable.

d.

e.

8. Do you think this is a realistic case? Were there any key facts, conditions, considerations that were not in the case, but should have been? If so, Explain.

Yes

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